A Feasibility Study for a Micro-hydro Installation for the Strangford Lough Wildfowlers & Conservation Association

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Copyright Declaration

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Abstract

Micro-hydro is an ancient source of renewable energy and, in the light of government CO_2 reduction targets and funding incentives, is currently being considered for installation in locations where sustainable water resources exist. This thesis is concerned with a feasibility study for a micro-hydro scheme on a conservation site in Newtownards, Northern Ireland. The conservation site has an existing 10m dam behind which is a 4 acre lake; water flows through an existing outflow pipe continuously throughout the year. A survey of the site was undertaken to determine the available head, flow rates and possible locations for the turbine. Discussions with Northern Ireland Electricity (NIE) established costs and the issues of integrating a distributed generator, at the conservation site, into the national electricity grid. The study confirmed that the concept of a micro-hydro scheme using the existing dam is sound, and that a peak sustainable power output of 54kW could be achieved using a high efficiency vertical axis turbine. A new intake would need to be constructed with a 500mm penstock to a pre-fabricated turbine house beneath the dam at a 15m head. A sustainable operational schedule was used for the purposes of the study (based on discussions with the conservation site owners) to enable an analysis of the possible annual income for different NIE tariff charges.

The owners of the conservation site have a passion for the environment, and over the last 50 years have safeguarded this unique nature reserve. The socio-economic and environmental impacts of the proposed micro-hydro scheme are discussed in detail in the thesis. The literature review of micro-hydro shows that no scheme around the world has real-time performance data which is available over the web. This study gives an overall design of a data acquisition scheme with a mock prototype web page showing real-time system performance.

Finally, it is estimated that a net income of £13,950 per annum could be achieved for a total capital cost of £268,000. With the maximum grant funding of £100,000 from Clear Skies and 25% funding from the Northern Ireland Electricity Smart Fund, the owners of the site would have to raise just under £100,000.

Section I – General

1.1 Introduction

Energy demands are increasing on a global scale. The energy demands from developing countries such as China are set to rise exponentially. This places significant pressure on the earth's finite resources while producing increased CO_2 emissions. The UK has signed up to meet CO_2 emission reduction targets as part of the Kyoto Protocol. To meet these emission reduction targets government policies has ensured an influx of renewable energy in the UK. The majority of renewable energy in the UK is currently produced by large-scale hydro and wind farms. However, it is predicted that smaller distributed energy systems will increase with rising electricity prices and government incentive schemes such as Renewable Obligation Certificates.

Northern Ireland does not generate enough electricity to match its demand and has recently installed a 275kV high voltage direct current (HVDC) interconnector from Scotland supplying up to 500MW from Scottish Power. In addition, Northern Ireland penalises heavy electricity users with a seasonal time of day tariff. This results in many industrial users switching to diesel generators with cheaper operating costs during this time to supply their electricity needs. However, this form of energy increases the strain on the finite resources. The country has a growing economy and, hence, rising energy demand [13] with the option to supply electricity demands from distributed generators becoming increasingly attractive. This thesis investigates the feasibility of installing a micro-hydro-generator in a conservation site in Northern Ireland.

1.2 Micro-hydro

Water is a natural resource which has been used to generate power, in one form or another, for centuries. In its simplest form hydro power was used to grind grain, provide shaft power for textile plants, sawmills and other manufacturing operations [5]. These small hydro power sites could be found in many locations throughout Europe and North America.

The development of centrally-generated electric power eventually reduced the requirement for small hydro sites. These developments fuelled a growth in large-scale hydro-electric schemes where dams were constructed to store water and generate, in many cases, mega-watts of power. As a result, the majority of sites with potential for large-scale hydro-electricity in the UK have been exploited [14]. The trend is shifting in hydro electricity developments, with installations now reflecting small scale developments similar to the ones of centuries past. Micro-hydro turbines with high efficiencies have aided the move back towards small distributed sites.

Micro-hydro is defined as the generation of electricity from a few hundred watts to 100kW [10]. There are currently 24 micro-hydro sites throughout the UK [11]. However, thirteen of these sites are mills with waterwheels, or in one case a Francis turbine, typically installed between 1910 and 1960. The most recent hydro-electric installation was in 2003 in Grantis Mill, Somerset where a 15kW hydro-generator was installed [11]. The two principal reasons for a low uptake in micro-hydro installations in the UK in the past are; excessive capital cost and environmental impacts. To negate these barriers to micro-hydro development, sites which have an existing infrastructure are more attractive to micro-hydro developers. In addition, government grants are available for community orientated renewable projects to aid the installation and contribute towards reducing emissions.

Two such grants are Clear Skies and Northern Ireland Electricity (NIE) Smart Fund. The £10 million “Clear Skies” initiative aims to give homeowners and communities a chance to become more familiar with renewable energy by providing grants and advice. Community organisations can receive up to

£100,000 for installations and up to £10,000 for feasibility studies. Funding support for feasibility studies will be available to community schemes, to help address key issues such as technical and financial viability, legal and planning issues, and access to other sources of funding. The feasibility study is used as an application for renewable energy installation funding. The scheme is operating in England, Wales and Northern Ireland (excluding Isle of Man and Channel Islands), and was introduced in January 2003, and is planned to operate for 2 years [16].

NIE's SMART (Sustainable Management of Assets and Renewable Technology) has funds available to support renewable energy and demand side management initiatives. There is up to £250,000 per annum available to support projects installing near-market renewable technologies, including: solar water heating, photovoltaics, micro-hydro, small scale biomass, ground source heat pumps and micro CHP. The applicant is eligible if they fall into one of the following categories: community group, business, housing association, public sector and charities or voluntary organisations [17].

1.3 The Project

The Strangford Lough Wildfowlers and Conservation Association is a cross-community group whose membership is open to the public throughout Northern Ireland. The Association provides members with access to wildfowl shooting on Strangford Lough from islands that they own in the lough. The Association, being conscious of the need for conservation, breeds wildfowl at two locations in Newtownards to ensure wildfowl stocks are not depleted as a result of their shooting activities. The Association owns the fishing, shooting, mineral and water rights on their property.

Figure 1: Map of Northern Ireland

Sourced: www.nidex.com/map.htm

One of the areas used to breed wildfowl is the Glen Vale Conservation Area just north of Newtownards town centre. This area was purchased by the association over fifty years ago and comprises a 4 acre lake formed from a dammed-up quarry, surrounding woodland and a lower pond used for breeding. Four rivers from the catchment area run into the lake providing a continuous flow of water throughout the year, even in dry weather. The dam was formed over 100 years ago to supply water to two textile mills in Newtownards and the valve house at the base of the dam still has outflow pipes leading to the town. The lake is assessed to be about 10 metres at its deepest point. The lake is used by the local fishing club, another cross-community organisation open to the public, who have full access to the site. The Association stocks the lake with brown trout for the fishing club, and the lake also has a natural stock of brown trout.

The site, however, is not currently open to the general public because of significant concerns about security, vandalism and the maintenance of the area as a nature reserve. The site is opened for an annual open week when members of the Association are present to allow members of the public access to raise awareness on the conservation work undertaken on the site. The manner in which this site could be better utilised has long been on the Association's agenda. A proposed micro-hydro installation is intended to generate income for the Association to enable it to improve facilities on the site including the construction of a visitor centre, better and safe access for school parties and world wide access via the internet.

1.4 Methodology

The Campbell Palmer Partnership Ltd (who sponsored the fulfilment of this Master of Science Degree) presented the opportunity to undertake a feasibility study for a micro-hydro Installation for the Strangford Lough Wildfowlers & Conservation Association (SLW&CA). The work within the dissertation has been carried out throughout the duration of the study, by the author.

The purpose of the study is to analyse the technical, social, legal and environmental feasibility of a micro-hydro installation on the SLW&CA site. Moreover, this entire process will be integrated to present a methodology for potential income from the plethora of electricity tariffs and use of system charges for distributed generators such as the proposed micro-hydro installation.

The first phase of the study was to recognise the components of a micro-hydro system. A literature review of hydro-electricity was carried out. This review presented an understanding of the technology and the components required to perform a field study, and to establish potential performance characteristics. A review of the electricity grid identified the issues associated with connecting distributed generators to operate in parallel with the electricity network.

The second phase of the study involved meeting the key personnel involved in the proposed developments at the SLW&CA site in Northern Ireland, and undertaking a preliminary survey of the site. The intended idea of the SLW&CA was to use the existing water flow from an ancient penstock on the site. Discussions were centred on environmental concerns, community involvement and the need for the project. It was identified from the meeting that the SLW&CA wanted to maintain the existing flow from the penstock and weir in the Lake. By doing this, the amount of water taken from the lake will not be altered in any way. For this reason it was decided that it would be unnecessary to survey the catchment area of the lake.

On the second visit to Northern Ireland a meeting was arranged with the Distributed Generation Manager for Northern Ireland Electricity (NIE) to discuss grid connection issues with the proposed micro-hydro-generator. In addition possible income streams were also examined.

An in depth survey of the site was undertaken on the second visit to Northern Ireland. There is no historical data for the flow rate from the outflow or weir. The flow rates from the existing pipe and weir were measured using an anemometer and possible locations for the generator site assessed with a theodolite and staff. The manufacturer of the anemometer confirmed that as well as being able to measure wind velocity the instrument could also be used to measure water velocity. The Chairman recorded the flow from the weir for a period of 4 months. From the survey it was possible to estimate mean and peak flow rates and analyse optimum penstock diameter to maximise the head. Discussions with SLW&CA, local council and community helped identify the environmental impacts of the project.

The findings from the second survey were used to contact potential micro-hydro installers. Two installers replied with capital cost guidelines for the proposed micro-hydro project.

Following the survey, a sustainable operating schedule for the micro-hydro scheme was established and, hence, generation profiles were examined from NIE tariffs and use of system distribution charges. This permitted an analysis of the potential income by exporting energy from the micro-hydro scheme to specific customers with different tariff structures.

The final stage of the study was to assess the financial viability of the proposed micro-hydro installation. The capital costs, ongoing annual costs and possible sources of finance were integrated to identify whether the micro-hydro scheme could be cost effectively installed on the SLW&CA site.

1.5 Brief Overview

This dissertation comprises seven sections which are discussed below:

Section 1. *General*, presents an introduction, the subject and major focus of the study and structure.

Section 2. *Literature Review*, reviews relevant literature within the hydro electric work field, investigating core concepts of energy production from water, the technology of hydro-electricity, and the requirements for connection of distributed generation in parallel with the Northern Ireland Electricity Grid.

Section 3. *Feasibility Study*, describes the proposed micro-hydro-electric scheme site and outlines the environmental and electrical grid connection issues relating to the site. In addition, this section details unique features of the proposed hydro installation and the educational benefits to the local community.

Section 4. *Technical Analysis,* documents the findings from the survey of the site.

Section 5. *Analysis of Potential Energy Resource and Income from Exported Energy,* uses the data gathered from the site survey to develop a methodology for assessing the potential energy and income for the SLW&CA.

Section 6. *Financial Viability,* includes the cost of installing a micro-hydro scheme on the site, operating costs of the scheme, available funding and the final cost to the SLW&CA.

Section 7. *Conclusions and Recommendations*, presents conclusions and scope for further studies and development.

Section II – Literature Review

2 Hydro Generation

2.1 Conversion of Water Power to Electricity

Nearly a quarter of the energy from the sun that reaches the Earth's surface causes water from the seas, lakes and ponds to evaporate [20]. A proportion of this energy is used to make water vapour rise, against the gravitational pull of the Earth into the atmosphere, where it eventually condenses to form rain or snow. When it rains in the hills or snows in the mountains, some of the solar energy input remains stored. Therefore water at any height above sea level represents stored 'gravitational' energy [2].

This energy is naturally dissipated by eddies and currents as the water runs downhill in streams and rivers until it reaches the sea. The greater the volume of water stored and the higher up it is, then the more available energy it contains. For example, water stored behind a dam in a reservoir contains considerable 'potential' energy. To capture this energy in a controlled form, some or all of the water in a natural waterway can be diverted into a pipe. It can then be directed as a stream of water under pressure onto a water wheel or turbine wheel. The water striking the blades causes the wheel (or turbine) to turn and create mechanical energy [10].

The hydro electric plants work by converting the kinetic energy from water falling into electric energy. This is achieved from water powering a turbine, and using the rotation movement to transfer energy through a shaft to an electric generator.

2.2 Hydro Technical Review

This section provides a brief technical review of hydro power. Hydro electricity generation is considered a mature renewable technology, with extensive textbooks and journal papers which have covered the subject in detail. For this reason a brief review of the technical aspects are presented below.

2.2.1 Stored Potential Energy

A water flow from an upper to a lower level represents a hydraulic power potential. The difference between the level of the upper reservoir z_{res} and the level of tail water z_{tw} is defined as the available head [18].

Available Head,

$$H_{AV} = z_{res} - z_{tw}$$

The potential energy to move 1kg of water from the upper to the lower level is given by:

$$PE = gH_{AV}$$

Where

PE is the potential energy (Joules)

g is the acceleration of gravity (9.81ms^{-2})

H_{AV} is the available head (m)

2.2.2 Power Output

The available power from the hydro is given by the equation [18],

$$P = \rho QgH_{AV}$$

Where

P is the available power of the hydro scheme (W)

ρ is the density of water (kg/m^3)

Q is the flow rate of the water (m^3/s)

Effective head (H_{EF}). In real hydro systems the water delivered to the turbines will lose some energy as a result of frictional drag and turbulence as it flows in channels and pipes. Thus, the effective head will be less than the available head [18].

System Efficiency (η). The efficiency of turbines varies according to the type of turbine and the flow rate into the turbine. The system efficiency considers both the combined efficiency of the generator, converting mechanical to electrical energy, and the turbine [18].

Hydro Turbine Power Output,

$$P(W) = \eta \rho Q g H_{EF}$$

2.3 Types of Hydro-Electric Schemes

2.3.1 Run of River

The first hydro facilities were known as Run of River schemes [3]. The schemes do not include any significant water storage, and therefore make use of whatever water is flowing in the river. When streams and rivers have low flow, run of river

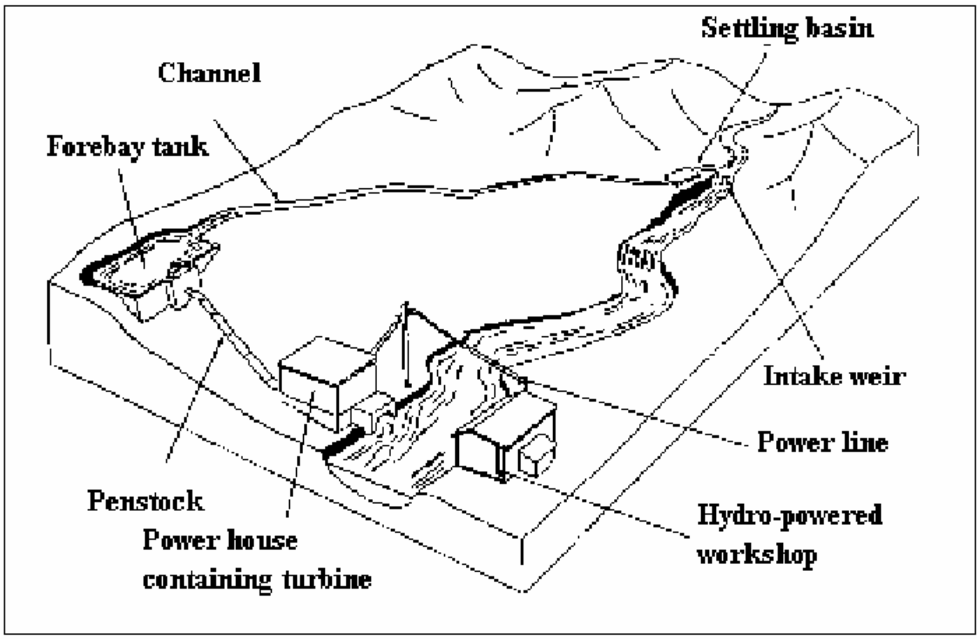

Figure 2: Layout of a Run-of River Hydro Scheme

Sourced: www.itdg.org

schemes are unable to generate power. A typical run of river scheme involves either a low level diversion weir (a small dam) or a stream bed intake, and are usually located on swift flowing streams [14]. A low level diversion weir raises the water level in the river sufficiently to enable an intake structure to be located on the side of the river. The intake consists of a trash screen and submerged opening with an intake gate. An alternative arrangement (not requiring a weir see Figure 2 above) is to have a streambed intake where the water drops through a screened inlet duct that has been installed flush with the bottom of the riverbed. A streambed intake will allow rocks and gravel to enter which means the design must include a screen to flush out the debris in the system. Water from the intake is normally taken through a pipe (penstock) downhill to a power house constructed downstream of the intake and as at low a level as possible to gain the maximum head of the turbine.

2.3.2 Dam Based

Hydro schemes may also be based on the construction of a large dam to store water and to provide sufficient head for the turbine. These water storage schemes enable the power station to generate at times of peak power demand, and then allow the water level to rise again during off peak time. Schemes with large dams are better suited to larger, gently graded rivers [20]. The advantage of this type of plant is that they have the capability to store the energy (water) and use it when necessary.

2.3.3 Pumped Storage

Pumped storage plants utilise a reversible pumping turbine to store hydro energy during off-peak electricity hours by pumping water from a lower reservoir to an upper reservoir. This stored energy is then used to generate electricity during peak hours, when electricity is costly to produce, by distributing water from the upper to the lower reservoir.

2.4 Types of Turbines

Hydro turbines can be broadly categorised into either impulse or reaction turbines [10]. Impulse turbines convert the kinetic energy of a jet of water in air into movement by striking buckets or blades. By comparison, the blades of a reaction turbine are totally immersed in the flow of water, and the angular as well as linear momentum of water is converted into shaft power. The types of turbines are discussed in more detail.

Impulse Turbines

2.4.1 Pelton Turbines

The Pelton wheel was developed in California during the Gold rush days of the 1850s [21]. The Pelton turbine consists of a set of specially shaped buckets mounted on a periphery of a circular disc. The disc is turned by jets of water, which are discharged from one or more nozzles, striking the buckets (see Figure 3). The buckets are split into two halves so that the central area does not act as a dead spot incapable of deflecting water away from the oncoming jet. The cutaway on the lower lip allows the following bucket to move further before cutting off the jet, propelling the bucket ahead of it, and also permits a smoother entrance of the bucket into the jet. The Pelton bucket is designed to deflect the jet through 165 degrees (not 180 degrees which is the maximum angle possible without the return jet interfering with the following bucket for the oncoming jet). In large scale hydro Pelton turbines are normally only considered for heads above 150m, but for micro-hydro applications Pelton turbines can used effectively at heads down to about 20m. Pelton turbines are not used at lower heads because their rotational speed becomes very slow and the runner required is very large and unwieldy.

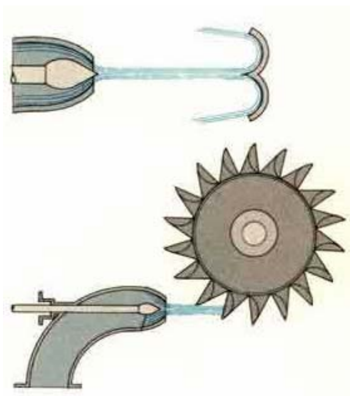

Figure 3: Pelton Turbine

Sourced: www.waterwheelfactory.com

This is an efficient process of extracting energy from the flow of water (90%) when there is a very high head available [22]. To operate at a turbine efficiency of 90% the water flow must operate between 70% and 80% of the maximum flow (see Figure 4).

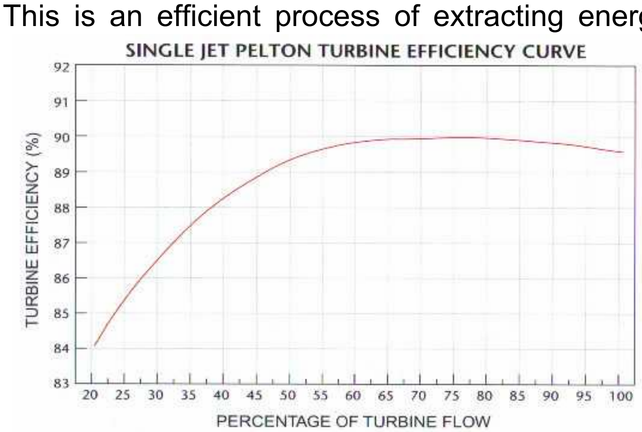

Figure 4: Single Jet Pelton Efficiency Curve

Sourced: www.newmillshydro.freeserve.co.uk

2.4.2 Turgo Turbines

The Turgo turbine is similar in design to a Pelton turbine, but was designed to have a higher specific speed [23]. In this case, the jets are aimed to strike the plane of the runner on one side and exit on the other. Therefore the flow rate is not limited by the discharged fluid interfering with the incoming jet (as is the case with Pelton turbines). As a consequence, a Turgo turbine can have a smaller diameter runner than a Pelton for equivalent power. The Turgo is efficient over a wide range of speeds and shares the general characteristics of a Pelton turbine including the fact that it can be mounted either horizontally or vertically. A Turgo runner is more difficult to make than a Pelton and the vanes of the runner are more fragile than Pelton buckets. They require about the same heads as do the Peltons and they sometimes employ multi jets to allow them to accommodate more water flow.

Figure 5: Turgo Turbine

Sourced: www.jyoti.com

2.4.3 Crossflow Turbines

A crossflow turbine has a drum-shaped runner consisting of two parallel discs connected together near their rims by a series of curved blades [15]. A cross flow turbine always has its runner shaft horizontal (unlike Pelton and Turgo turbines). In operation a rectangular nozzle directs the jet onto the full length of the runner. The water strikes the blades and imparts most of its kinetic energy. It then passes through the runner and strikes the blades again on exit (see Figure 6) impacting a smaller amount of energy before leaving the turbine. At low flows, the water can be channelled through either two thirds or one third of the runner, thereby sustaining relatively high turbine efficiency.

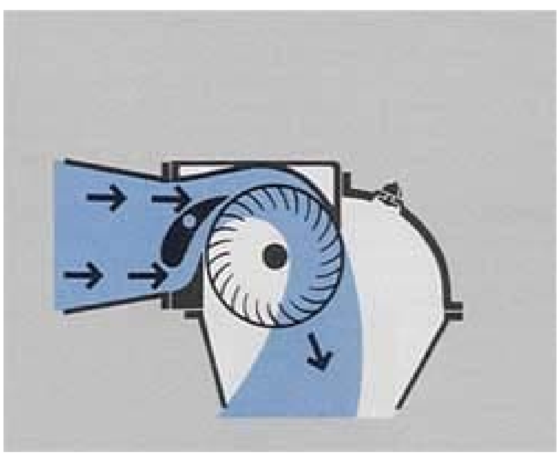

Figure 6: Crossflow Turbines

Sourced: http://www.ossberger.de/index

Reaction Turbines

2.4.4 Francis Turbines

The Francis turbines may be divided in two groups; horizontal and vertical shaft. In practice turbines with comparatively small dimensions are arranged with horizontal shaft, while larger turbines have vertical shaft. Francis turbines can either be volute-cased or open-flume machines. The spiral casing is tapered to distribute water uniformly around the entire perimeter of the runner and the guide vanes feed the water into the runner at the correct angle [19]. The Francis turbine is generally fitted with adjustable guide vanes. The runner blades are profiled in a complex manner and direct the water so that it exits axially from the centre of the runner. In doing so the water imparts most of its pressure energy to the runner before leaving the turbine via a draft tube.

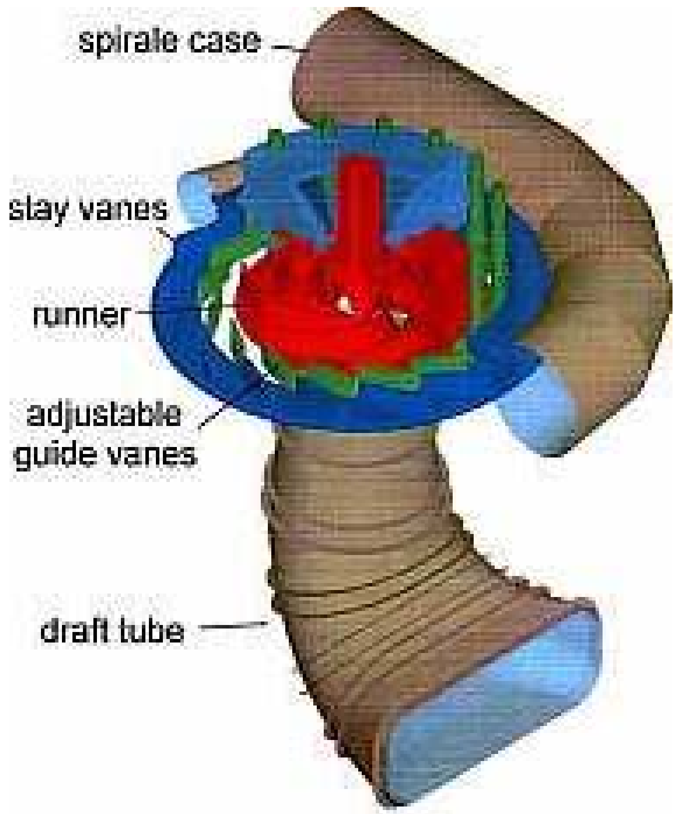

Figure 7: Francis Turbine

Sourced: www.cineca.it

The Francis turbine has the widest range of application among the various types of turbines available. Highly flexible, it comes in a range of different sizes that can operate under heads ranging from around 20 to 500 metres. When the turbine's flow rate is reduced below 85% of the maximum flow, the efficiency of the turbine falls away (see Figure 8) [22].

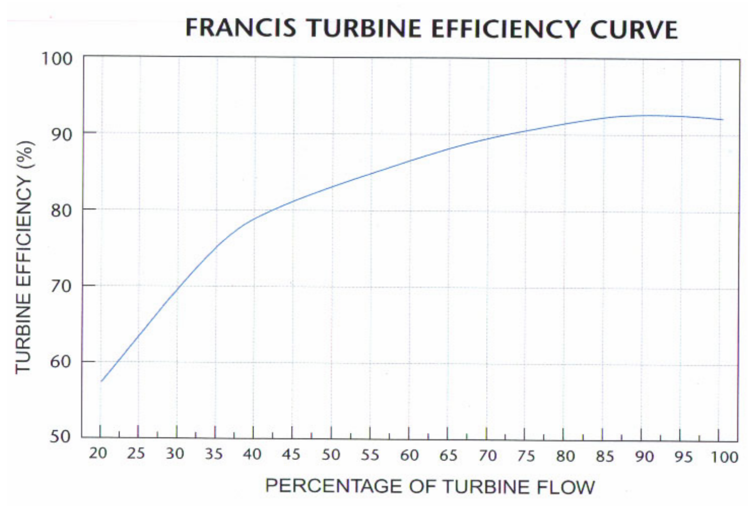

Figure 8: Francis Turbine Efficiency Curve

Sourced: www.newmillshydro.freeserve.co.uk

2.4.5 Propeller Turbines

The basic propeller turbine consists of a propeller, similar to a ship's propeller, fitted inside a continuation of the penstock tube (see Figure 9). The turbine shaft passes out of the tube at the point where the tube changes direction. The propeller usually has three to six blades or swivel gates just upstream of the propeller. This kind of propeller turbine is known as a fixed blade axial flow turbine because the pitch angle of the rotor blades cannot be changed. The part-flow efficiency of fixed-blade propeller turbines tends to be very poor [20].

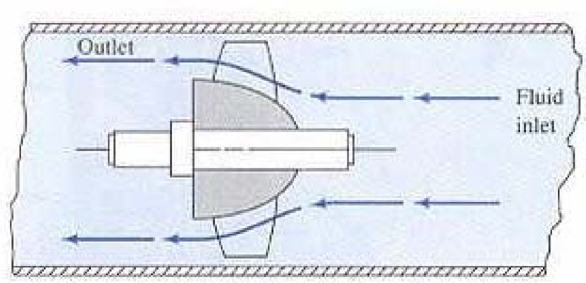

Figure 9: Propeller Turbine

Sourced: bioen.okstate.edu

2.4.6 Kaplan Turbines

Large scale hydro sites make use of more sophisticated versions of the propeller turbines. Varying the pitch of the propeller blades together with wicket gate adjustment enables to handle a great variation of flow very efficiently. Such turbines are known as variable pitch or Kaplan turbines (see Figure 10). The Kaplan runner is a development of the early 20th century and can only be installed in the vertical orientation, Kaplan turbines have a high specific speed which means that direct coupling to the generator is possible but only at higher heads and lower flows [19].

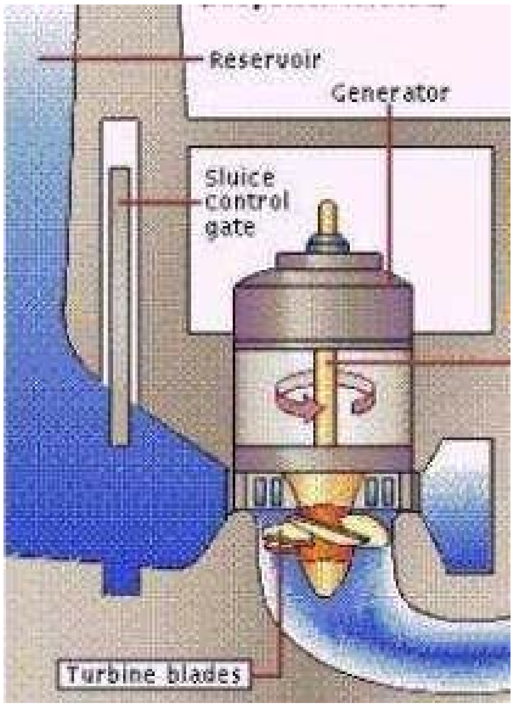

Figure 10: Kaplan Turbine
Sourced: www.shomepower.com

This means that a speed increase will be necessary on most applications. The Kaplan turbines are 90% or better in efficiency when turbine flows are 35% or greater than the maximum flow (see Figure 11), but are very expensive and, hence normally used in larger installations [22].

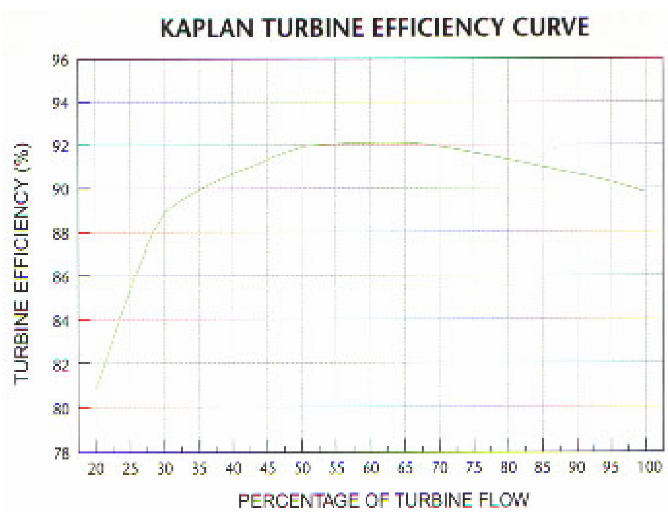

Figure 11: Kaplan Turbine Efficiency Curve
Sourced: www.newmillshydro.freeserve.co.uk

2.4.7 Bulb Turbines

Bulb turbines are named after the shape of their upstream watertight enclosures. The generator is accommodated within the enclosure and therefore submerged in the water passage (see Figure 12).

Suitable for low heads and large discharge/head variations, bulb-units have virtually replaced Kaplan turbines for very low heads sites [19]. This is because the near straight design of the water passage improves the hydraulic characteristics of the flow, giving both size and cost reductions. The bulb turbines have been utilised however, more widely, in tidal power installations such as La Rance in France. For very low heads, generator speeds have to be increased by means of gears.

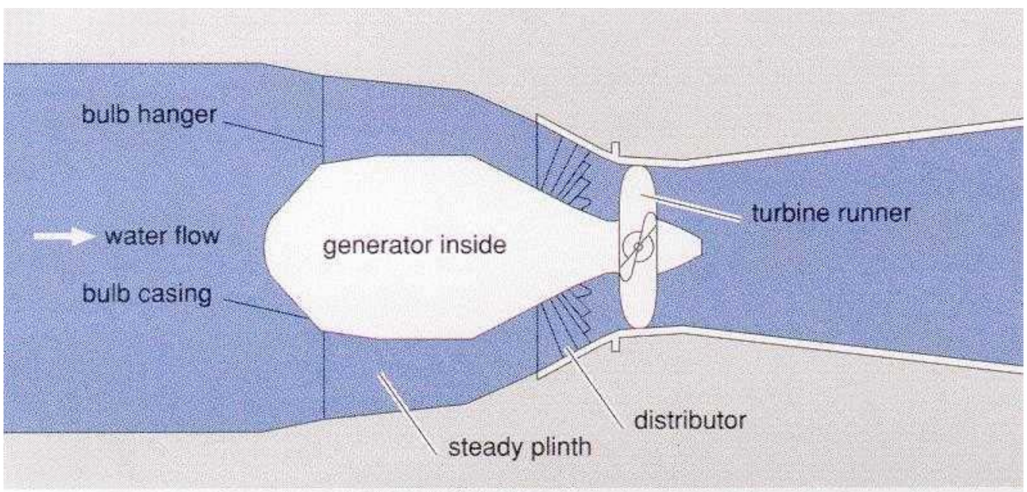

Figure 12: Bulb Turbines

Sourced: acre.murdoch.edu.au

2.5 Turbine Selection Chart

The turbine selection chart below permits the user to select turbines for a given flow rate (m^3/s) and head (m).

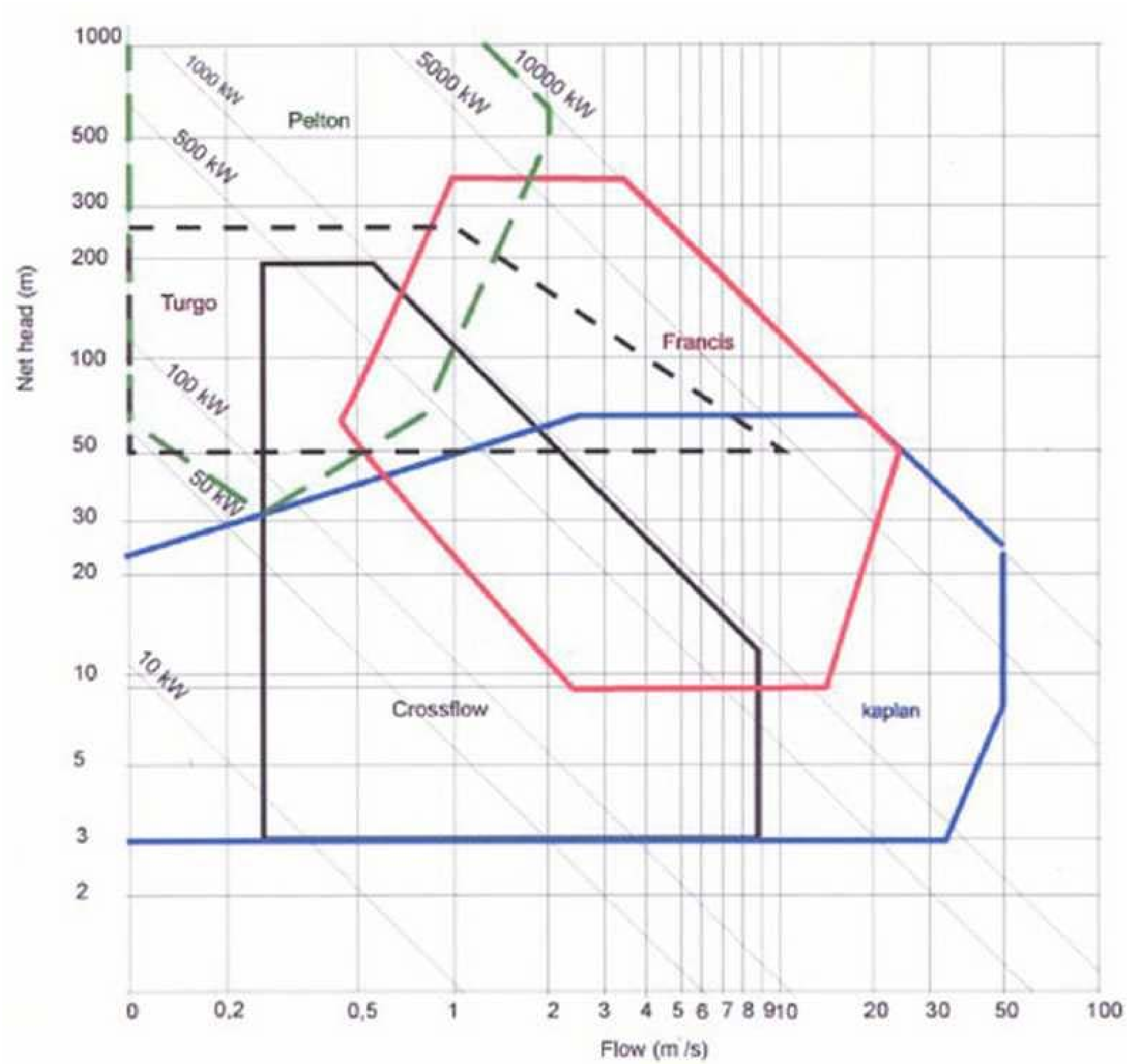

Figure 13: Turbine Selection Chart

Sourced: www.newmillshydro.freeserve.co.uk

The area within the blue line represents a Kaplan or Bulb turbine

The area within the red line represents a Francis turbine

The area within the green line represents a Pelton turbine

The area within the dark dashed line represents a Turgo turbine

The area within the black line represents a crossflow turbine

2.6 Governors

Turbine governors are equipment for rapid control and adjustment of the turbine power output and evening out deviations between power and the grid load. The governor system can be mechanical-hydraulic, electro-hydraulic, or digital hydraulic [24]. The systems, regardless of type have the following three components:

- The controller, which is the unit used for control of the hydro installation
- The servo system, which is an amplifier that carries out water admission changes determined by the controller
- The pressure oil supply system, which is used to supply oil to the servo system

The turbine governors purpose is to keep the rotational speed of the turbine-generator stable at any grid load and water flow in the turbine conduit. During load rejections or emergency stops the turbine water admission must be closed down according to acceptable limits of the rotational speed rise of the unit and the pressure rise in the water conduit.

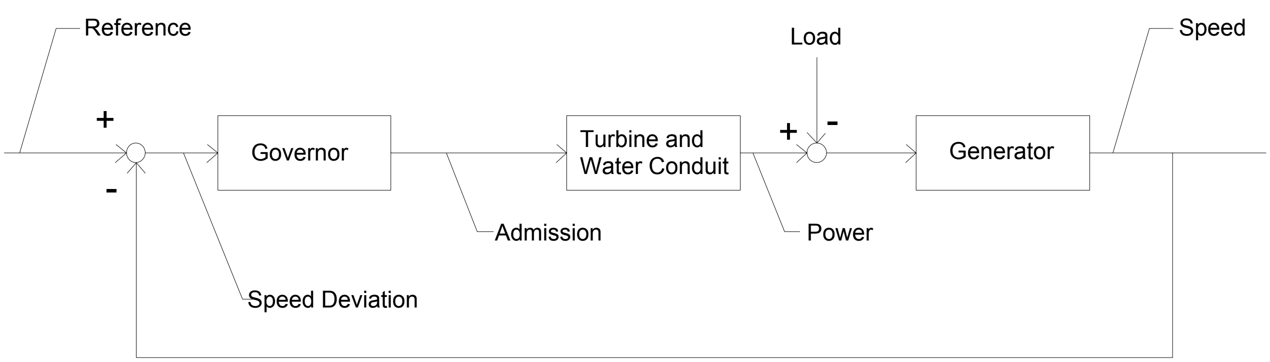

Figure 14: Governor Function

Figure 14 above shows the function of the governor. The input reference signal is compared with the speed feedback signal. With a momentary change in the load a deviation between the generator power output and load occurs. The deviation causes the unit inertia masses either to accelerate or to decelerate.

The output of this process is the speed, which is again compared with the reference.

2.7 Hydro-Electric Generators

2.7.1 Synchronous Generators

A synchronous generator can be connected to a micro-hydro turbine and can operate either connected to the grid or as a stand-alone generator. The generator operates at a speed directly related to the frequency. However, when the micro-hydro turbine is connected to a synchronous generator, which is directly connected to the electric grid, a speed variation is not possible. If speed variation is not possible, system efficiency is reduced because the generator cannot adapt to a partial load. There are also safety issues with synchronous generators which include; voltage regulation, islanding, and speed and frequency control.

2.7.2 Induction Generators

Induction generators rely on a connection to an outside source of power, ie the electricity network, to establish and control the rotating magnetic field. This makes this type of generator a safer option than other types of generators for connection to the grid. However, in the absence of grid connection it is possible for induction generators to generate power if it is connected to a sufficient source of capacitance reactance, such as capacitors. In this case very high voltages will be produced , causing a hazard to the equipment [4].

2.8 Civil Works

2.8.1 Dams

Dams are classified according to their profile and building material, which is typically concrete, earth or rock. The civil works for a hydro electric scheme typically accounts for 60% of a plant's initial investment [14].

2.8.2 Concrete Dams

Concrete dams can be divided into solid gravity, hollow gravity, and arch dams. The gravity dam relies on its own weight to resist hydraulic thrust. The hollow gravity dam contains about 35% of the concrete required for a solid dam, but is more expensive per unit volume. The arch dam, is designed for narrow valleys and distributes the hydraulic thrust to its abutments.

2.8.3 Rockfill and Earthfill

Rockfill and earthfill dams usually have a core which is covered with loose rock or earthfill. Grass may even be grown on the earth fill. Water will seep in through the earth or rock fill, but should not seep into the core.

2.8.4 Canals and Channels

The canal conducts the water from the intake to the forebay tank (see Figure 2). The length of the channel depends on local conditions. Most canals and channels are excavated to reduce friction and prevent leakage, channels are often sealed with cement, clay or polythene sheet. The size and shape of a channel are often a compromise between costs and reduced head. As water flows in the channel, it loses energy in the process of sliding past the walls and bed material. The rougher the material, the greater the friction loss and the higher the head drop needed between channel entry and exit.

2.8.5 Settling Basin

The water drawn from the river and fed to the turbine will usually carry a suspension of small particles (see Figure 2). The sediment will be composed of hard abrasive particles such as sand which can cause damage and rapid wear to turbine runners. To remove this material the water flow must be slowed down in settling basins so that the silt particles will settle on the basin floor. The deposit formed is then periodically flushed away.

2.8.6 Forebay Tank

The forebay tank forms the connection between the channel and the penstock (see Figure 2). The main purpose is to allow the last particles to settle down before the water enters the penstock. Depending on its size it can also serve as a reservoir to store water. A sluice will make it possible to close the entrance to the penstock. In front of the penstock a trashrack is normally installed to prevent large particles entering the penstock

2.8.7 Penstock

The penstock is the pipe which conveys water under pressure from the forebay tank to the turbine. The penstock often constitutes a major expense in the total micro-hydro budget, as much as 40% is not uncommon in high head installations, and it is therefore worthwhile optimising the design [12]. The trade-off is between head loss and capital cost. Head loss due to friction in the pipe decrease dramatically with increasing pipe diameter. Conversely, pipe costs increase steeply with diameter. Therefore a compromise between cost and performance is required.

2.9 Scheme Banding

The size of a hydro-electric facility is classified by its power output. The table below shows five hydro-electric categories with their associated power outputs. The chart below the table attempts to illustrate the breakdown of hydro-electric sites in the UK [11]. It shows that medium hydro (15 to 100MW), mini-hydro (above 100kW but below 1MW) and small hydro (1 to 15MW) account for the largest proportion of hydro schemes in the UK.

Table 1: Scheme Banding of Hydro Electric Schemes

Size of Hydro Electric Facility	**Power Output**
Large hydro	More than 100MW
Medium hydro	15 to 100MW
Small hydro	1 to 15MW
Mini-hydro	above 100kW but below 1MW
Micro-hydro	Ranging from a few hundred watts up to 100kW

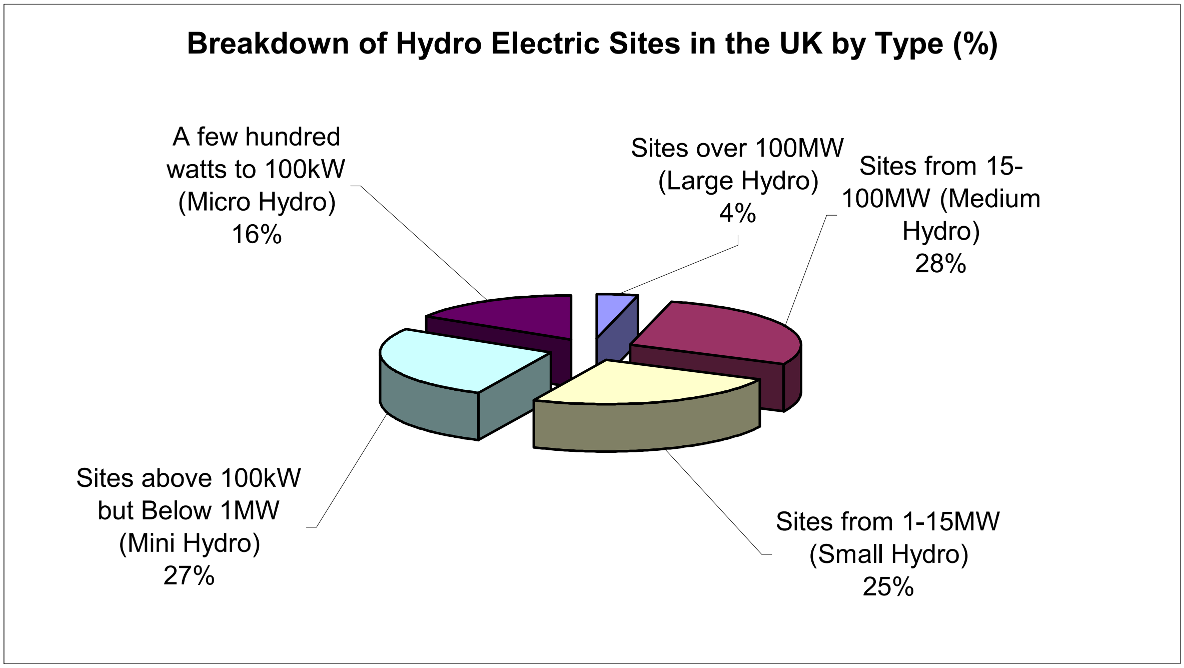

Figure 15: Breakdown of Hydro-Electric Sites in the UK by Scheme Banding

2.10 Micro-hydro Schemes in the UK

The table below shows lists all of the micro-hydro installations found in the UK. It can be seen that the majority of installations were before 1990 and relate to the textile industry. There is no performance data available from any of these installations [11].

Table 2: Location of Micro-hydro Schemes

Location	Hydro Location	Power Output	Installation Date
Argyll	Inver. Isle of Gura	30 kW	1984
Scottish Highlands	Eliock House	36 kW	1977
Gwynedd	Brynkir woollen mill	10 kW	1960
	Brooklyn Mill	20 kW	1904
Somerset	Gantis Mill	15 kW	2003
Stirling	Ashfield House Hydro	6 kW	1995
Wiltshire	Crabb Mill	5 kW	1890
Worcestershire	Fradbury Mill	18 kW	1981
Yorkshire	Armitage Bridge		
Avon	Avon Power Station	89 kW	1957
Cartmarthenshire	Cwmcych Mill	10 kW	Not Available
	Cwmorgan Mill	10 kW	Not Available
	Dreifa Mills	10 kW	1880
	Godremamog Mill	10 kW	Not Available
	Mars y Felin	10 kW	Not Available
Ceredigion	Rheidol	50 MW	1961
Cheshire	Pedley Wood	2 kW	1991
	Staveley Millyard	30 kW	2002
Derbyshire	Errwood Reservoir	100 kW	1989
Devon	Changford Power Station	20 kW	1891
	Fernworthy Damn	5 kW	1957
	Holne Park	40 kW	1981
	Old Walls Hydro	90 kW	1995
Dumfries & Galloway	Maidenholm Forge Mill	30 kW	1946

3 Grid Network Review

3.1 Northern Ireland Overview

Northern Ireland has an emerging economy resulting in a rising demand for electricity [13]. There are problems meeting this demand from existing power generation plants, and consequently an expensive seasonal time of day tariff (STOD) was introduced to heavy users. This was designed to try and reduce demand at certain times of the day when there was not enough capacity to meet demand. This has resulted in many industrial and business users switching to standby generators (in most cases powered by oil) during the STOD tariff period to reduce energy costs.

In 1990, NIE signed agreements with Scottish Power for the construction of a 275kV high voltage direct current (HVDC) interconnector between the companies' transmission systems. It took nine years of planning applications, public inquiries and environmental statement procedures before NIE obtained the statutory consents for the transmission line, undersea crossing and converter stations [25]. The submarine cable has a power transfer capability of 500MW.

The link supplies Northern Ireland with an important new source of electricity supply, which will promote electricity in the emerging markets in Northern Ireland and the Republic of Ireland, as well as enhance security and quality of supply.

3.2 Northern Ireland Electricity

The transmission system in Northern Ireland is owned and maintained by Northern Ireland Electricity (NIE). Power in Northern Ireland is generated by four power stations which are owned by independent companies. The power stations are linked to 30 substations by 275kV double circuit transmission lines, 110kV double and single circuit lines. The substations distribute electricity to consumers via 33kV transmission lines [13].

3.3 Distributed Generation

Environmental legislation and government targets to reduce CO_2 emissions have increased the integration of renewable energy generation into distribution networks. The renewable energy technologies are often small-scale and include micro-hydro, small wind turbines and micro combined heat and power. The majority of these schemes can be found in remote rural areas where the electrical distribution structure can be considered weak and underdeveloped.

The existing electricity network architecture was not designed to accommodate the reverse flow of electricity from distributed sources. This can pose a number of problems for the network operators. These are discussed as below:

- Maintaining voltage and frequency control within statutory limits
- Reduced power factors and increased losses due to the reactive energy consumed by generators
- Automatic disconnection of a generator (islanding) is not designed to cope with reverse power
- Harmonic distortion can cause stress in a distribution system and result in additional heating in equipment, transformers, capacitors and wiring, resulting in wasted energy.

The strain placed on the electricity network can be reduced where the generation technology matches a local load within the distribution system. This reduces the requirement to transport electricity in the reverse direction and hence, reduces network demand and distribution losses.

3.4 Technical Requirements to Operate Distributed Generation in Parallel with the NIE Network

3.4.1 Introduction

The operation of any distributed generation will, potentially have implications for NIE in respect of the way in which it operates its networks and the quality of supply provided to other customers. The level of involvement and cost implications for NIE is dependant on the type and size of the generating capacity. A preliminary investigation is carried out by NIE in to the connection of a proposed distributed generator to assess firstly, the feasibility and secondly, an indicative cost for the project.

3.4.2 Procedure to Facilitate Connection

A generator questionnaire must firstly be completed and returned to NIE where the proposal will be considered. NIE may request that the distributed generator applicant pay NIE alteration charges and NIE will arrange for the work to be carried out. A generator capacity agreement and a blank copy of the embedded generation test record will be provided by NIE. The distributed generator applicant must also advise NIE of the intended electricity trading arrangements. It is the responsibility of the applicant to ensure any installation is in accordance with G59/1/NI Recommendations for the Connection of Embedded Generation Plant to the Public Electricity Suppliers' Distribution System.

3.4.3 G59/1/NI

G59/1/NI is an engineering recommendation document from the Electricity Association regarding the safety and protection requirements of connecting embedded generating plant to public electricity suppliers' distribution systems. The document also contains the legal aspect of connecting embedded generating plant to public electricity suppliers' distribution systems. The recommendation applies to systems to be connected at, or below, 20kV and where the generating plant output is less than 5MW [5].

<u>Technical Factors within G59/1/NI [5]:</u>

Fault Infeed. The level of fault infeed from the generator must be established before installation to assess what impact the generator will have on the fault level of the public electricity supply.

Synchronising. If a synchronous generator is used, the generator must be synchronised with the public electricity supply before parallel connection. During parallel connection the voltage fluctuation should not be greater than 3% at the point of connection.

Distortion and Interference. The embedded generator may produce harmonic voltages and currents which could cause harmonic distortion of the public electricity supply.

Isolation. The public electricity supplier has the right to disconnect the embedded generators supply of electricity to the distribution network for safety reasons.

Protection Equipment. The generator protection system must be able to detect the following:

- Over voltage
- Under voltage
- Over frequency
- Under frequency
- Neutral Voltage Displacement
- Over current
- Earth Fault
- Reverse Power
- Loss of mains

Section III – Feasibility Study

4.1 The Glen Vale Site

The Glen Vale site is a private nature reserve containing a 4 acre lake, which is referred to locally as the high dam, and the Glenvale Conservation Area. A structural and underwater survey of the dam was carried out in February 2003, and the dam was reported to be in good condition. The lake level is controlled by an outlet from a brick valve house positioned at the base of the dam and an overspill located at the north-east corner of the lake.

A lower pond, which is fed from the lake, is located 15m below and 145m from the valve house outlet. This pond is manmade and used to breed wildfowl. At the south end of the lower pond a sluice distributes the water into a concrete drainage pipe where the water flows from the SLW&CA site and connects with Newtownards drainage system.

4.2 Micro-hydro Scheme Concept

Having established that the dam is in good condition it was suggested to the Association that the site could be suitable for a micro-hydro-generator scheme. The existence of the dam structure together with the much reduced requirement for civil engineering works, make for an excellent site for a micro-hydro scheme. The current sustainable flow rate from the existing outlet would be maintained with the installation of a hydro-generator, virtually eliminating undesirable ecological and environmental impacts which would otherwise result from such an installation.

The purpose of the hydro-scheme is to provide a stable source of income for the Association by becoming an energy supplier. The intention is to wheel electricity over the Northern Ireland Electricity (NIE) distribution network to an organisation capable of taking the full output from the generator 24 hours a day. Wheeling is the term used in the electricity sector for transporting electricity over transmission and distribution lines to consumers.

4.2.1 Ards Borough Council

Two meetings were held with officers of Ards Borough Council, the first at the start of the study and the other later in the study. In addition, many issues have been discussed over the telephone with the Local Agenda 21 officer.

4.2.1.1 Meeting at Ards Borough Council

The purpose of the meeting was to discuss the Council's involvement in the feasibility study and arrangements for the supply of electricity to a nominated Council building. The principal outcomes were:

1. The Council agreed in principal to the purchase of electricity wheeled over the NIE network to a nominated council site. This would most likely be the Exploris Marine Visitors Centre, the Northern Ireland Aquarium in Portaferry on the Ards peninsular, which has a baseload of 85kVA and a maximum demand of 160kVA. The centre has a number of large seawater pumps which operate continuously to replenish and oxygenate the seawater tanks. With a maximum possible output of 54kW from the proposed hydro-generator, Exploris would be able to take the entire output of the generator continuously. Exploris has a seal

Figure 16: Exploris Marine Visitors Centre

Sourced: www.exploris.org.uk

Sanctuary (see Figure 16) and a reputation for rescuing injured seals for re-release into the wild. Its environmental credentials and educational commitment make it an ideal partner for the proposed hydro project.

2. Council electricity tariff structures were discussed, and a Seasonal Time of Day electricity tariff applies to the building in question. Subsequent to the meeting the details of the electricity tariff structure for Exploris were provided.

3. General discussions were held concerning the extent and nature of the community involvement required to secure a Clear Skies Grant for the proposed hydro project. It was felt that emphasis should be placed on educational activities rather than recreational activities as these could, more realistically, be regulated by the Association. Various ideas for this were discussed.

4. The Council offered the services of their Local Agenda 21 officer to assist with the feasibility study.

4.3 Meetings with the Strangford Lough Wildfowling and Conservation Association

Two meetings and many discussions have been held with office bearers of the Association. The initial meeting was held with Jack Gilliland, chairman of the Association, and Robert Morrison the Hydro-Scheme Project Officer. They provided the background information about the Association and the site. A number of issues in relation to the local environment were discussed.

An evening meeting was held at the Association's clubhouse at Glen Vale to meet the entire committee including the head of the angling section. Also present at the meeting was Ursula Toman of the Local Energy Efficiency Advice Centre. A lively two hour discussion enabled Association members to ask questions on all aspects of the proposed scheme including: hydro generation; the water resource available; possible engineering solutions; environmental impacts; funding assistance; and increase access and the use of their unique site in a controlled manner.

4.3.1 Dialogue with the Local Community

Dialogue with the local community has been ongoing for some time as the Association has been seeking to make better use, and create better public access to, the Glen Vale Conservation area. Support has been forthcoming from local councillors which resulted in the active involvement of Ards Borough Council. Jim Shannon, the MLA member of the Northern Ireland Assembly for the Newtownards area, in his role as a Local Agenda 21 office bearer, has visited the site and is enthusiastic for the proposals.

4.3.2 Support from Educational Establishments

Letters were sent to local schools, colleges and Queens University Belfast advising them of the project and the educational opportunities presented. Letters of support were received from the University, two secondary schools, Killard House the special needs school, and three primary schools (see Appendix F).

4.3.3 Details of Existing Community Involvement and Input

The Association has been very active in the field of conservation and the members work towards the maintenance of wild life habitat including the preservation of wild birds. A bird rearing programme is operated where wild duck eggs are collected under license, hatched and brought-on to be released into the wild. For these efforts the Association has been awarded the Stanley Duncan Trophy for Conservation on no less than three occasions and more recently has won the North Downs Rotary Club award for Conservation.

The education of the public, in particular younger children, to the ways of country sports and country life is a long term constitutional objective of the Association, and to this end the Association's grounds have been opened up on an annual basis to the general public and local schools for over 30 years. Currently the conservation area is opened to the public for the second week in

June and the number of visitors coming to the open week in some years has numbered several hundred. The schools that visit regularly include several of those who replied in support of the hydro scheme. They are mainly primary and infant school children, but regular visitors are groups of disabled pupils from Killard Special Care School. In the past the visitors and schools have been able to use the 'Conservation Hall', located on the site, to view displays and carry out curriculum based nature study classes. However, concerns over the condition of the asbestos roof and wall cladding have led to the building being closed. A short term Association objective is to replace this building with a Visitor Centre which can be utilised on a regular basis by schools.

The 4 acre lake is open to Club anglers, and day tickets are available to the public. However, access to the water's edge is not suitable for those with certain physical disabilities. It is an aspiration of the Association to provide parking and improved access so that disabled anglers can also enjoy the benefits of the facilities. The lower pond is to be developed to provide coarse fishing for a junior angling club, the membership for which will be drawn from the local community including disadvantaged children in association with the Ards Community Network.

4.3.4 Public Profile

The planned publicity together with the plans to construct a visitor centre and make information available on the internet should result in high public profile for the project. This is especially so considering the several unique features of this project. The provision of data on the performance of the hydro system which is not currently available on the internet for any other UK micro-hydro installation will assist in the understanding of renewable hydro energy generation.

4.3.5 Public Access

The site being privately owned by the Association has never been open to the general public except for an annual open week. The income generated by this project will enable a greater level of public access to be achieved in a structured and safe manner which also protects the fragile eco-system in the nature reserve. The Association is currently formalising the access arrangements to the site for the general public, and these arrangements will be notified through the local press once in place.

4.3.6 The Need for the Project

The objectives of the micro-hydro project are to generate income for the Association to enable it to fulfil its goals, and to generate renewable electricity to reduce the carbon emissions from the recipient organisation. From the responses received to the Association's letter to educational establishments, the need for improved access and a quality visitor centre on the Glen Vale site are clear. The most pressing need is to generate regular income in order that schools and the general public can benefit fully from improvements to the site.

Once the improved facilities and improved access are in place it is estimated that several classes of pupils from each of the local schools will visit the site every year. This could amount to 1,000 or more school pupils visiting the site each year. It is expected that a site with hydro generation technology on view will attract a lot of public interest and that public visitor numbers on open days will increase significantly, again drawing over 1,000 people a year. Improved access to disabled people and disabled anglers could bring further visitors.

The visibility presented by the Association's proposed website will bring world-wide recognition to this unique site. Not only will thousands, perhaps tens of thousands, of people visit the website, but this also draws in increasing numbers of people interested in renewable energy generation by hydro power.

The Newtownards Electoral Ward is designated as a socially disadvantaged area. Together with the cross community nature of the Association, a significant opportunity is presented to serve the needs of disadvantaged children in a cross community setting.

4.3.7 Promotion of the Scheme

As facilities are developed at the site it is planned to invite the local press to run articles on the development and the facilities to be provided. Initially, publicity is planned following the feasibility study and the Association is pursuing the possibility of a feature article with the local newspaper. Further publicity is planned once a contract has been let for the hydro scheme. Both Ards Borough Council and the Local Energy Efficiency Advice Centre are very supportive of the scheme which they each plan to use for publicity purposes.

4.4 The Contribution of the Micro-hydro Scheme to the Local Community

In addition to the generation of green electricity for sale, the proposed micro-hydro scheme would be one component of a range of improved educational opportunities for schools, colleges and universities. It would enable a stable income to be generated to provide the educational facilities presented by this site. Learning opportunities include the study of nature, ecology and renewable energy. It is hoped that, with the support of the local communities, the project will be able to create employment through the development of this amenity which is part and parcel of the local heritage of the town of Newtownards.

4.5 Meeting with Stephen Thompson of Northern Ireland Electricity

A meeting was held with Mr Stephen Thompson of NIE Connect who is the desk officer for embedded generator connections in the Belfast area. The following is a summary of the discussions:

- Wheeling of electricity using NIE system should not be a problem. NIE would charge 2.5p per kWh
- An electricity sub-station located at the rear of Saratoga Avenue (approximately 200m from the site) could be used to accept output from the generator. NIE will provide a budget cost for connection.
- The length of cable run should be kept as short as possible as the voltage rise can be a significant problem for long lengths of cable. The maximum permitted voltage rise between the NIE substation and the

hydro-generator is 10% or approximately 24 volts. The longer the cable run the heavier the cable needs to be to limit this voltage rise.

- NIE will provide a high level design before a more detailed design for the system is completed
- G59 protection equipment could be located by either in the hydro-generator house or on the site boundary. If the former, NIE would lay cable all the way. If the latter NIE would lay cable to site boundary only. If protection equipment located on site boundary planning permission would be required for a secure housing.
- The G59 protection requirements in Northern Ireland vary slightly from those on UK mainland:
    - Under frequency trip at 4%
    - Automatic reconnect delay after fault disconnection a minimum of 1 minute
- The generator house must have background trace heating installed
- NIE sends 2 documents: a wheeling agreement and their pre-connection questionnaire
- Options for sale of electricity are to identify a nominated recipient and wheel electricity over the NIE network. If, for example, the client pays 6p/kWh when the wheeling charge is taken off this produces an income of about 3.5p/kWh for the Association. If electricity sold to NIE a rate of 3p/kWh was quoted, this is inclusive of the wheeling charge.
- NIE is particularly concerned that a maintenance contract is in place with a reputable and experienced contractor.
- It is proposed that Renewable Obligation Certificate (ROCs) will be available to all renewable generation by 2005 irrespective of the size of generator.
- There are a number of different tariff structures which must be considered eg seasonal time of day (STOD) tariff.

4.6 Unique Features of the Project

4.6.1 Educational Potential

There are several micro-hydro schemes operating in the UK, the full educational potential of which are not exploited to their full. A visit to a micro-hydro installation generally enables the penstock, turbine, generator and outflow to be viewed. This provides a qualitative experience but does not necessarily enable a proper understanding of the system or its performance. With the instrumentation proposed for this project (a lake level monitor, a rainfall monitor, flow meter in the penstock and electricity meter on the generator output) linked into the control system it will be possible to monitor lake level, flow rate, generator power output and power factor in real-time. The data produced will also enable the hydro-turbine-generator system efficiency to be calculated in real-time. All of this data will be displayed in real-time on a monitor in the proposed visitor centre.

4.6.2 Wider Educational Access via the World Wide Web

By installing a web server and permanent internet connection, and linking the data outputs from the control system into it will be possible to view the performance data on the system in real-time via the internet. Research has revealed that, at present, there is no hydro-generator site in the world which puts real-time data onto a website. This project will be unique in that it will be a world first providing students from secondary school to university throughout the world the opportunity to monitor a micro-hydro site remotely in real-time.

It is also intended to log all of the above data on the web server so that complete data sets encompassing one year’s worth of data can be downloaded from the website. Complete data sets would enable comprehensive analysis of the performance of this particular hydro system, and would allow hydrologists to compare water flow rates and lake levels with rainfall in the area. This could provide another income stream for the Association if downloadable data is made available on a subscription basis, and the income generated would contribute towards the cost of operating the web server.

4.6.3 CCTV Monitoring of the Site

CCTV monitoring will be installed to monitor selected areas of the nature reserve or particular activities on the reserve. CCTV monitors will be positioned in the visitor centre from where visitors will be able to watch wildlife activities on and around the lake, and on the lower pond non-intrusively. The monitor outputs will be extended to the web server to provide a webcam service. This will allow remote monitoring of the reserve for both educational and security purposes. Schools will be able to monitor what happens on the reserve throughout the year, and the Association's members will be able to monitor poachers and other unauthorised access to the site.

4.6.4 Educational Access to the Site

A steady income from the hydro system will enable the Association to upgrade the site progressively making it safe for educational parties to use the site for nature walks and wildlife projects. At present the paths are not in good condition, there are no guard rails where paths cross streams, the steps to the high dam are uneven and there is no hand rail.

4.6.5 Disabled Access

At present disabled access to the site is very limited, and the Association is in the process of upgrading this access. The money generated by the hydro scheme will enable further improvements in disabled facilities on the site including access for wheelchair bound members of the fishing club as well as members of the public.

4.6.6 Proposed Waterwheel

The correspondence with Queen's University Belfast resulted in Gerald Müller, a lecturer in mechanical engineering, expressing an interest in the installation of a modern high efficiency waterwheel on the site. This could be installed at the outlet from the lower pond using the same water flow and generating a further small quantity of electricity. Queens University is currently applying for funding to construct a full size prototype waterwheel. With the existence of a hydrogenerator on this site, the additional mains electrical connection required could be provided at low cost. Similarly, a means for the University to monitor the performance of the waterwheel remotely in real-time could be provided via the web server.

This would provide an example of modern (hydro-generator) and historical (waterwheel) methods of generating renewable energy from water. Gerald Müller and this author know of no other installation in the UK, or the world for that matter, with a micro-hydro-generator and waterwheel installed on the same site. An installation of this nature would provide a unique opportunity for University students and research fellows to monitor the performance of both technologies.

5 Legal Considerations

5.1 Ownership

The Strangford Lough Wildfowlers and Conservation Association is currently an unincorporated association. At a recent special general meeting the Association members agreed to change the legal status of the Association to a Private Limited Company, limited by Guarantee. The new status will enable the Association to own and operate the proposed hydro scheme.

The Association owns the Glen Vale conservation area and the water rights in the area.

5.2 Management of the Scheme

The scheme will be managed by the Association under an operating contract with a local company. Day-to-day responsibility for the safe and correct operation of the hydro-generator will rest with the contractor. Northern Ireland Electricity has a statutory responsibility to ensure the electrical safety of the system and its requirements in respect of connection to the NIE network, system maintenance and the contractual arrangements required between NIE and the Association, and the Association and its maintenance and operating contractor. NIE made it clear that it would not sanction a connection to its system unless it was wholly satisfied with the competence and experience of the operating and maintenance contractor.

5.3 Planning Considerations

In Northern Ireland the Planning function is carried out by the Northern Ireland Civil Service. Mr George Martin is the planning officer responsible for Newtownards and has been consulted about the proposed Hydro-generator Project. His initial reaction was very positive and, like many of the people contacted during the study, was engaged by the possibilities presented by the scheme. He confirmed that planning permission will be required for the installation of the new intake, penstock and hydro-generator house. However, the nature and location of the installation is not expected to result in any formal planning objection. The Environmental Heritage organisation should be contacted prior to the submission of a planning application.

5.4 Other Statutory Obligations

The upgrading of a 450mm drainage gully will require the approval of The Northern Ireland Rivers Agency, and the formal agreement of the land owner through whose land the drainage gully passes.

Section IV - Technical Analysis

6.1 Map and Photographs of The Glen Vale Site

The map below shows the position of the lake, dam, valve house, pond, sluice and other features of the site in conjunction with representative photos. The map location references are shown in section 6.2.

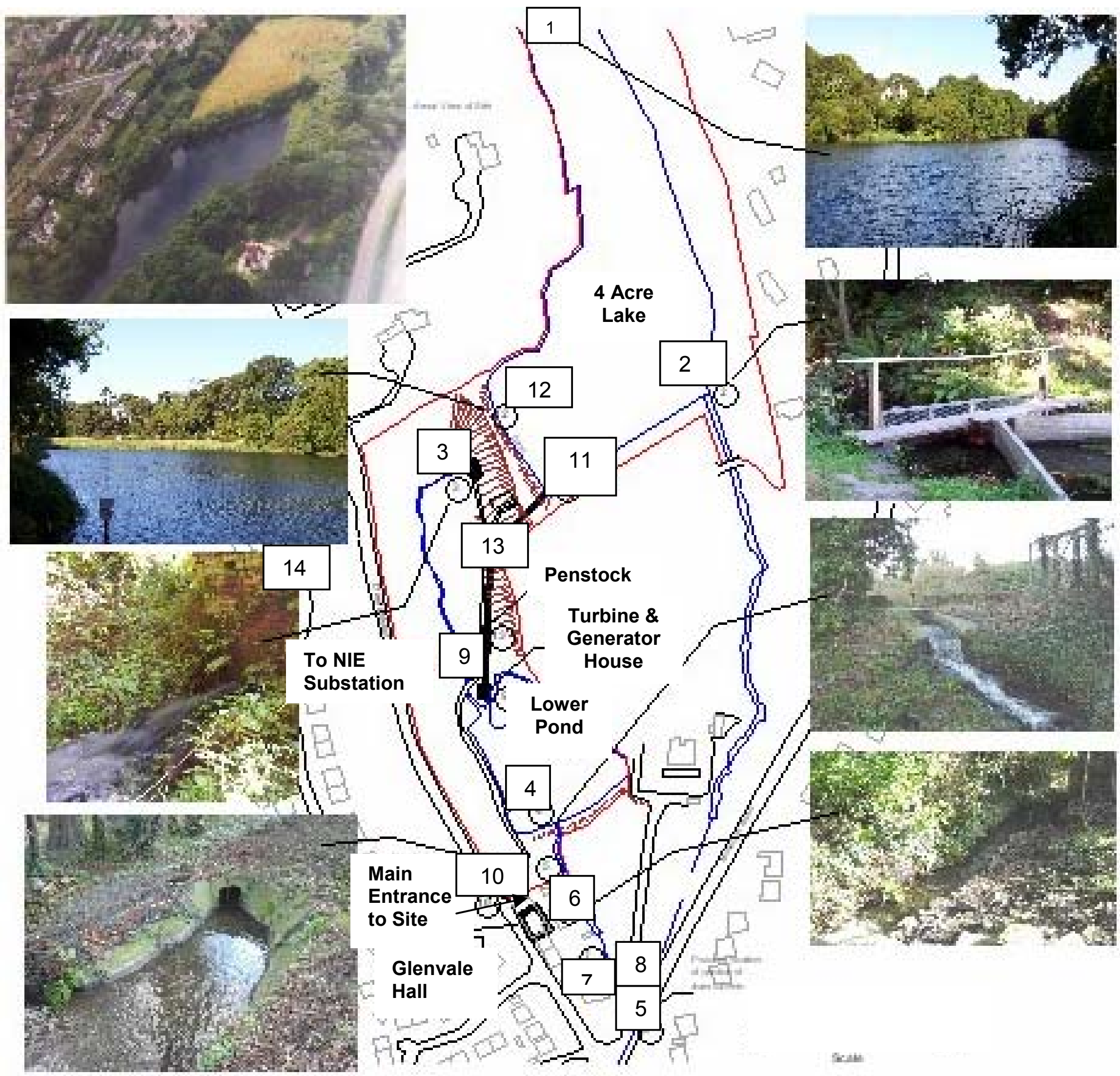

Figure 17: Map and Photographs of The Glen Vale Site

6.2 Map Location References

1 Inflow to 4 acre lake

2 Main outflow over weir

3 Valve house

4 Outflow from lower pond

5 Outflow from site in 550mm diameter concrete culvert

6 Location where stream wall to be rebuilt

7 Final outflow into 450mm diameter concrete culvert

8 Probable location of junction of drain culverts

9 Proposed location for hydro-generator house

10 Main entrance to site

11 Proposed location of new intake

12 High Dam

13 Route of Penstock

14 Location of NIE Sub-Station

6.3 Site Survey

The objectives of the site survey were to:

- Identify environmental considerations
- Determine water flowrates from the valve house outlet and at the overspill
- Assess the available head
- Identify possible locations for the hydro-generator

6.4 Environmental Considerations

Environmental considerations are always an important consideration when planning a hydro electric generation scheme. Many potential impacts were examined with the following results:

6.4.1 Hydrological Aspects

The 4 acre lake is fed by four streams which, together, provide a continuous flow of water throughout the year. While flows are greatest in the winter, a substantial amount of water flows into the lake even during a dry summer. The locations referred to below are detailed on the map of the Glen Vale in section 6.1.

6.4.2 Silting-Up of Final Inflow Stream (Location 1 on Map)

A number of silt traps exist on the final inflow stream to the lake. These have not been maintained with the result that the lake has silted up gradually over the last 50 years reducing its maximum depth from about 13m to 10m. The Association recognises that it will be necessary to repair these traps in the near future to prevent further silting of the lake and to reduce the amount of silt passing through the hydro turbine. Restoring the traps will have no undesirable environmental impact.

6.4.3 Water Flow Rate in the Main Overflow Channel (Location 2 on Map)

Much of the outflow from the lake flows over a weir at the south east corner of the lake into an open drainage channel. As this channel dries up in the summer, and can be 0.5m or more deep in the winter, diverting most of this water to supply the hydro-generator and reducing the flow of water in this overflow channel would not result in a significant environmental impact.

6.4.4 Water Flow in the Outflow from the Existing Valve House (Location 3 on Map)

The smaller outflow from the existing valve house runs down a stream bed to service the lower pond. Installing a hydro-generator would bypass this short stream but discharge directly into the lower pond. The lower pond would experience an increase in mean flow rate through the pond. Again, no undesirable environmental impact is likely to result.

6.4.5 Outflow from the Lower Pond (Location 4 on Map)

The outflow from the lower pond passes into a large drainage channel 1.6m below the level of the pond. Increasing the flow rate through the lower pond would have no measurable effect on the pond.

6.4.6 Outflow from the Site (Locations 5, 6, 7 and 8 on Map)

At the point it leaves the site (Location 5), the drainage channel from the lower pond passes into a 550mm diameter concrete drainage gulley for a very short distance. Beyond that it passes through the garden of a private house in an open stream, and then past another house before entering a 450mm diameter concrete drain where it remains underground as it passes beneath the town centre of Newtownards. Two areas of concern were identified:

1 Where the drainage channel passes through the garden of the private house (Location 6) previous owners have removed part of the original channel wall to form a rock garden feature leading into the water. During a full flow test from the valve house this caused the stream partially to overflow into the garden. In discussion between the owner and the Association Chairman the owner was both supportive of the plans for the hydro scheme and agreed to allow the stream wall to be reconstructed by the Association.

2 Of greater concern is the 450mm final outflow pipe (Location 7). A further site survey found this section to comprise three 3.5m concrete sections, the first having a 2^{o} slope and the other two sections being horizontal. Beyond these three sections the concrete pipe joins a much larger culvert beneath Mountain Road. The assessed location of this junction is shown on the map as Location 8. In discussion with the Northern Ireland Rivers Agency they advised that no records of either outflow from the site exist, and that their records begin some 300m to the south of the site. In order to accept the full flow of $0.5m^3/s$ from the hydro-generator system it would be necessary to upgrade the 450mm diameter section.

6.4.6.1 Consultation with The Northern Ireland Rivers Agency

Mr Frankie Mallon of the Northern Ireland Rivers agency was consulted concerning the capacity of the 450mm diameter drainage culvert leaving the site, its route slope and length before it connects with the main drainage channel coming from the existing lake overflow. The Rivers Agency has no drainage records for this part of Newtownards. Before contracts are let on the hydro project it will be necessary to undertake an intrusive investigation to establish the route and length of the 450mm section. A provisional sum has been included in the costings for this investigation and the upgrading of the pipe.

6.4.7 Water Flowrate through the Hydro-turbine

In order not to disturb the balance of water flow through the lake, and to maintain lake levels close to the present summer minimum/winter maximum levels, it is intended not to draw more water from the lake than the sum of the existing outflows at the overflow and valvehouse. This will result in a minimum continuous flowrate through the turbine sufficient to generate over 20kW of electricity while enabling up to 54kW to be generated when lake levels are high. Control of the water flow rate through the turbine would be by a lake level sensor which would operate the turbine at full power when the lake level exceeds a pre-determined level, and would switch the turbine off if a minimum lake level was detected.

6.4.8 Lake Level.

As the lake level in winter is often 1m higher than the mean annual level it is proposed to increase the lake level by 0.8m by raising the overflow weir. The structural survey of the dam raised no concerns about its structural integrity as its top is presently 1.5m above the mean water level. Raising the water level would have no undesirable environmental effects while increasing the lake store capacity significantly and the available head by 7%. The Association recognises that it would need either to cut a new pathway along the southern edge of the lake higher up the bank and/or construct a boardwalk just above water level for a distance of about 100m.

6.4.9 Fish Stocks

The Association currently has a problem with fish escaping over the weir during periods of high flow, and is obliged by the Fisheries Board to prevent fish escaping from the lake. Increasing the lake level and reducing the amount of water flowing over the overflow will both help to address this issue producing a positive environmental benefit.

6.4.10 Hydro System Intake

The hydro intake will be sited sufficiently below the water level to ensure that water is available down to the minimum acceptable lake level and that floating debris is not drawn into the intake, while minimising the pick-up of silt from the lake bed. Again, raising the lake level will assist in reducing the amount of silt carried through the hydro system. The intake will be fitted with a fish screen to prevent fish being drawn through the hydro system.

6.5 Other Environmental Aspects

Visual Impact. The hydrogenerator house (Location 9) and penstock will not be visible from outside the Glen Vale reserve and, thus, no visual impact issues are likely to arise.

Noise. The hydro-generator system will produce no more noise than is currently generated by the existing outflow weir. By siting the main water outflow from the lake at the lower pond the main source of noise will be moved further away from existing housing close to the conservation area.

Trees and Shrubs. While the conservation area has an abundance of mature trees, the proposed route of the penstock and location of the hydro-generator house will not require the removal of a single tree. Small shrubs and grasses will have to be cut back to allow the penstock to be installed, but once in place these will grow back to cover the penstock permanently.

NIE Power Cable. The NIE power cable will be routed down the Crawfordsburn Road and into the site. Once in the site it will be buried in soft ground up to the hydro-generator house. The laying of this cable will require access only for a mini-digger. Again no trees will be disturbed as a result of cable laying.

Vehicular Access and Plant Equipment (Location 10). The access to the site is less than 3.5m wide between two brick pillars. This will limit the size of plant and equipment which can be taken onto the site. The largest item of plant will be a small crane to lift the pre-fabricated hydro-generator house onto its concrete plinth.

6.6 Flow Measurements from the Valve House Outlet and Overspill

A miniature propeller vane anemometer (which can be used to measure water velocity as well as wind or air velocity) was used to measure the velocity of the flow of water from the valve house outlet and the overspill[1]. The velocity of water from the valve house outlet was measured at full flow and half flow (the normal setting of the flow) with the results described below:

- Full flow through the 200mm diameter outlet, the mean velocity measured was 3.9m/s giving a volumetric flow rate of $0.12m^3/s$

[1] The measuring instrument used was a Testo 435 meter with a 16mm diameter propeller vane 0635.9544 probe. The probe accuracy is ± 0.2m/s.

- Half flow, the normal operational setting where the water only exited from the lower half of the pipe, a mean water velocity of 1.78m/s was measured giving a volumetric flow rate of $0.03m^3/s$

Below is a sketch of the construction of the overspill. There was very little water depth over the weir[2], about 10mm, too small for the diameter of the measuring instrument, and the water was very turbulent. Hence, measurements were taken in clear laminar [6] flow about 100mm to the lake side of the loose rock barrier.

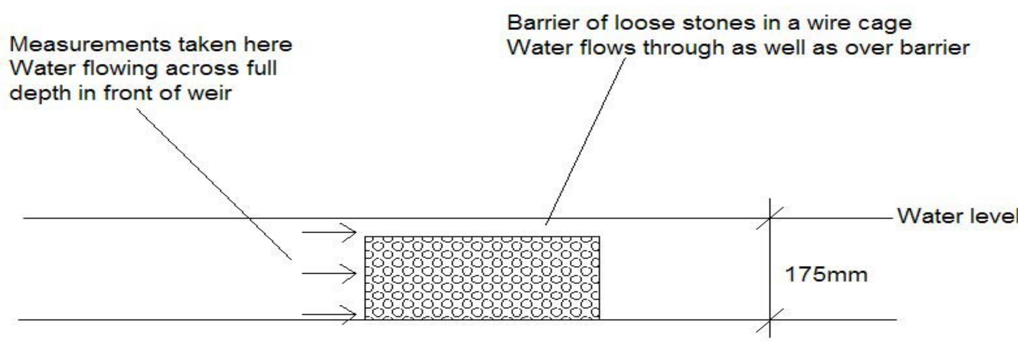

Figure 18: Sketch of Lake Overspill

The mean water velocity for the overspill, on the day of the visit, over a depth of 175mm and a width of 2.7m was 0.41m/s giving a volumetric flow rate of $0.19m^3/s$. The depth of the water was recorded by the Association from November 2003 to February 2004, with the results shown in the table below.

Table 3: Record of Overspill Depths

Date	Depth of Overspill (mm)
09/11/03	165
16/11/03	265
21/11/03	190

2 Most of the water was found to be flowing through the rock barrier forming the weir.

29/11/03	265
08/12/03	190
19/12/03	565
28/12/03	265
05/01/04	295
07/01/04	275
13/01/04	415
18/01/04	340
31/01/04	540
06/02/04	440
07/02/04	340
08/02/04	265
16/02/04	265
20/02/04	240
29/02/04	240

This shows that the flow rate over the weir measured during the site survey is typical of a winter flow. Currently, the water drained from the lake is maintained at half flow through the valve house outlet, whilst there is little or no water flow from the overspill during the summer and a variation in the flowrate in winter months. In a typical wet summer there is no flow over the weir for a period of four months, and in the worst case dry summer for a period of 6 months. A mean flow over the weir based on a weir depth of 175mm for the six winter months and zero flow over the weir during the summer six months is used for this analysis.

The figure below shows the existing valve house pipe arrangement where it was suspected, from the site survey, that there could be water flowing in branch pipes C and D. An investigation to determine if there was any flow in the two pipelines was carried out by the Association. An attempt was made to insert a flow meter in branch D but was unsuccessful as the pressure in the pipe was too great as valve 4 was found to be jammed open.

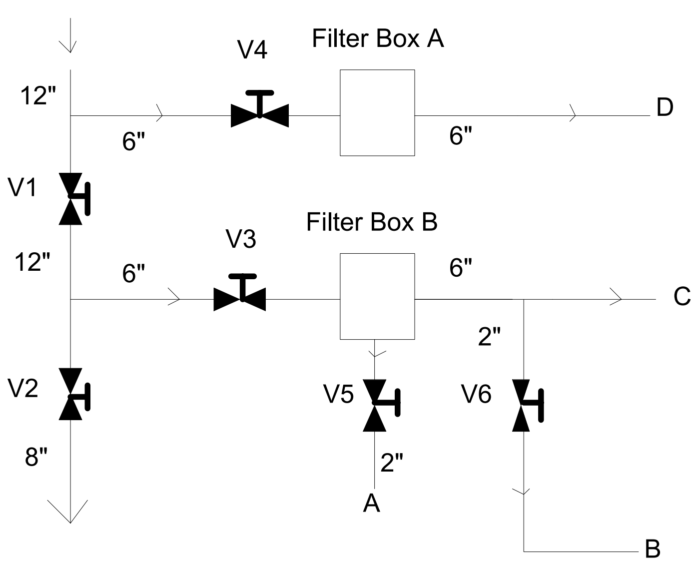

Figure 19: Existing Valve House Pipe Arrangement

There is a small possibility that water is flowing in branch D which would provide a greater water resource, but this could not be verified. Based on these findings it was decided that pipes C and D should be blanked off. By inserting plates where they come off the 12" main pipe section. The outflow would then be controlled by valve V2, which is currently operational.

6.7 Sustainable Flows

The lake water level has been maintained by setting valve 2 at the normal operational position for many years with no known adverse reaction to wildlife or the surrounding environment. For this reason the flowrates measured during the site survey are representative and should be considered sustainable. The sustainable winter flowrate is therefore the summation of the measured flowrate of water from the overspill (0.19m^3/s) and the measured flowrate from the valve house outlet at half flow (0.03m^3/s), giving 0.22m^3/s, while the sustainable summer flowrate is 0.03m^3/s.

A summer flow of 0.03m^3/s would result in an average daily outflow of 2,592m^3/day. This flow rate is too low to be of any practical use as it represents only 6% of the peak flow of a turbine matched to the peak flow. In order to be able to generate electricity in the summer months the number of hours for which the turbine could be operated would need to be reduced. As the minimum pragmatic flow through the turbine is about 30%, based on the turbine efficiency curve included in Section 7.2, the turbine could be operated at 30% flow for 4.8 hours per day or 33.6 hours per week on average. The financial analysis carried out to identify how to achieve optimum income from the turbine, indicates that it would be most cost effective to operate the turbine for 6.7 hours per day between 0800 and 2030 Monday to Friday in the summer months.

6.8 Available Head

Water located at a height represents stored energy. Thus, if the available head at the site is maximised the power output from the turbine will be increased. A theodolite and staff were used to measure the vertical drop from the centre of the existing 200mm outflow pipe to the lowest point on the site beneath the weir on the outflow from the pond. The results of the measurements are described below:

- The drop between the top of the dam and the lake level was measured as 1.5m, and using the 11.5m difference in level between the top of the dam and the valve house (contained in the underwater survey report) the head of the water from the lake to the centre of the 200mm outlet is 10m.

- A fall of 4.2m was measured from the centre of the 200mm outlet to the north bank of the pond, Location 9 on the map. If this is used as the turbine location a head of 14.2m would be available.

- A further 2.8m drop was measured from the north bank of the pond to the top of the 550mm concrete culvert pipe leaving the site, Location 4. If a turbine was located at the concrete culvert a head of 17m (10m + 4.2m + 2.8m) would be available.

- If the lake level is increased by 0.8m as agreed with between the Association and its fishing section, the available heads at locations 9 and 4 would be 15.0m and 17.8m respectively.

6.9 Possible Locations for the Hydro-Generator

A meeting with the Distributed Generation Manager at Northern Ireland Electricity (NIE) highlighted some important considerations for locating the hydro-generator on the site. Firstly, the nearest substation to the site is situated at the rear of Saratoga Avenue, Location 14 on the map, 200m from the Crawfordsburn Road and the closest point to the site boundary. Secondly, the length of cable run should be kept as short as possible as the maximum permissible voltage rise from the substation to the generator must is 10%. The longer the cable run the heavier the cable needs to be to limit this voltage rise resulting in additional cost.

Thirdly, the G59/1[3] protection equipment could be sited either in the hydro-generator house or on the site boundary. These factors will have to be considered in conjunction with the maximisation of the available head when deciding the optimum location for the hydro-generator.

It was initially suggested that the hydro-generator could be positioned in the existing valve house and connected directly onto the existing pipe, utilising the existing 10m head. However, the measurements revealed that the head could be increased significantly by situating the hydro-generator south of the valve house towards the pond at Location 9. The two possible generator locations and penstock (pipe) route are shown on the map as Locations 9 and 4. It is proposed that a new penstock be installed with a new inlet at Location 11 with the hydro-generator positioned 150m from the inlet at Location 9. Location 4 would incur far greater capital expenditure as a longer and larger diameter penstock would be required together with a heavier and longer electrical power cable. From the cost estimates received for the project, the capital cost would increase by at least £30,000 with a payback on this additional cost of more than ten years. Furthermore, locating the hydro-generator at Location 4 would require the penstock to run above ground around the lower pond causing a significant obstruction to access both the lower pond and the site, and unduly increasing the visual impact of the installation.

6.10 Optimum Position for the Hydro-Generator House

As part of the feasibility study, a specification was produced for the construction of a hydro-generator house, installation of the hydro-generator and pipework, control system and G59/1 protection equipment. The tender was sent to six hydro-generator installers selected from the Clear Skies Installers List, with a request for the installer to provide a recommendation for the optimum position of the hydro-generator house. Two of the six installers replied to the tender enquiry with both confirming that the optimal position for the hydro-generator house is Location 9.

[3] G59/1 is the engineering recommendation relating to the connection of embedded generating plant to public electricity suppliers' distribution systems.

6.11 Penstock Pressure Loss if Existing 300mm Pipe was to be Used

It was assessed, before measurements were taken, that the peak flow rate using the existing 300mm pipe from the existing lake bed intake to the valve house, could be of the order of $0.5m^3/s$, giving a power output of 49kW (before the efficiencies of the turbine and generator are taken into account) on an available head of 10m at Location 3. However, the measured flow rate of $0.12m^3/s$ (3.9m/s) from the valve house outlet on full flow did not match the predicted flow rate as the theoretical power output from the measured flow rate would be only 11.8kW, 37.2kW lower than expected.

Equating the kinetic energy in the measured flow to the potential energy required to produce that flow, the head for the measured velocity of water at full flow was calculated as 0.78m. As the actual head is 10m, 92% of the potential energy available is lost in the current pipe and inlet as friction and inlet losses.

The reason for this pressure loss on the existing pipe appears to be the result of three factors:

1 The cast iron was installed around 90 years ago, and judging from the condition of the pipes in the valve house, significant corrosion is present causing turbulent flow in the pipe and increasing the pressure loss.

2 The lake bed inlet is at least 40m from the dam face with a further 20m through the dam wall to the valve house, producing a significant pressure loss over 60m.

3 The lake has silted-up over time, which is beginning to cause the Association problems. The existing intake pipe appears to be clogged, verified by the substantial rotted leaf debris which collected on and fouled the measuring equipment during the survey. It is concluded from the analysis that the existing pipe could not be re-used for the hydro-generator.

6.12 New Intake and Penstock Route

It is proposed that the new intake be located at Location 11 shown on the map. The intake must be sufficiently deep that the inlet does not draw branches and other floating debris into the pipe, but not too deep that silt is sucked from the lake bed. Increasing the lake level by 800mm will greatly assist in achieving a location for the intake which meets these criteria. The location proposed is the site of the original overflow where the dam wall is lower and the earth is soft, making for a relatively simple penstock penetration through the top of the dam wall. The area is completely clear of trees and shrubs making the laying of the penstock relatively straightforward.

The Effective Head section in Appendix A shows possible power outputs from the hydro-generator based on the hydro-generator house situated at Location 9 for different penstock sizes. The effective head and, hence, power output is increased with a 500mm diameter pipe compared to a 400mm diameter penstock as the pressure losses reduce for an increased flow rate. The turbine installers recommended that a 500mm diameter penstock be installed.

6.13 Outflow from the Site

A number of issues were identified with the outflow. The original overflow weir from the lake was located where it is proposed to locate the new intake, Location 11. This overflow fed the lower pond and the stream leaving the site between Locations 5 & 8 took the full storm flow. It is not known why the location of the lake overflow was changed, but it appears that sections of the outflow stream were put into concrete drainage pipes at that time. The net result is that the outflow stream from the lower pond is unable to take the full storm flow from the lake and unlikely to be able to take the proposed peak flow of $0.5m^3/s$.

A site survey revealed that at some time in the past the owner of one of the properties through which the stream flows has removed the side wall of the stream for a distance of several meters. The stream is no longer contained at this point resulting in flooding of the owner's garden when the flow is higher than normal. Furthermore, the fragile condition of the remaining stream walls could result in erosion of the banks if a substantially higher flow occurs.

In order to avoid the need to replace the final 10.5m of 450mm diameter drainage culvert to where it joins the main drainage culvert beneath Mountain Road, it is proposed to:

- Install an automatic weir with pond level control on the lower pond

- Allow the level of the lower pond to rise to accept the large volume of water produced during the 3 hours per day of full flow operation in the winter. If the normal winter outflow rate from the lower pond is $0.22m^3/s$, which the 450mm culvert could handle, the lower pond level would rise by 0.72m over a 3 hour period. As the lower pond could accept a water level rise of about 0.4m without increasing the height of the banks, the outflow lip from the pond, and hence the lowest level for the automatic weir, would need to be lowered by just over 300mm.

- To duct the existing stream in a 450mm pipe all the way from the site outlet, Location 5 to the final outflow into the 450mm culvert, Location 7. Rivers Agency approval has been sought for this. Should this not be forthcoming, the walls of the stream would need to be re-constructed in a suitable material to ensure that erosion of the stream banks cannot occur.

6.14 Electrical Interconnection

The electrical schematic for the proposed hydro-generator installation is shown in the drawing in Appendix G. The generator will be of the asynchronous type and connected for parallel operation with the Northern Ireland Electricity (NIE) system. The electrical system in the hydro-generator house is to include the following:

- Hydro-turbine protection
- Generator Protection to G59/1 including
  - Over Voltage

- Under Voltage
  - Over Frequency
  - Under Frequency
  - Loss of Mains
- Generator and turbine connection to earth electrode

A 350m run of underground cable will be installed by NIE from the 11kV substation to the hydro-generator house. The installation will include NIE's own protection equipment and export metering.

7 Real-time Performance of Micro-hydro Scheme

Section 4.6.2 discusses the possibility of installing a real-time data acquisition system which can be viewed over the web, as an integral part of the SLW&CA micro-hydro scheme. An overall design schematic of the proposed data acquisition system for the SLW&CA hydro scheme is presented below.

7.1 Data Acquisition System

The data acquisition system would comprise four sensors to monitor lake level, water flow rate, power output and rainfall. Table 3 shows the type of sensor required in each case and the location of each sensor. The recorded data from the four sensors is delivered to a hydro-generator control system, to be located in the generator house which enables the generating plant to run unattended [26]. The hydro-generator control system would continually make adjustments to the hydro scheme by communicating with the sensors to open or close gates to ensure the optimal flow of water from the lake while protecting the ecology of the lake.

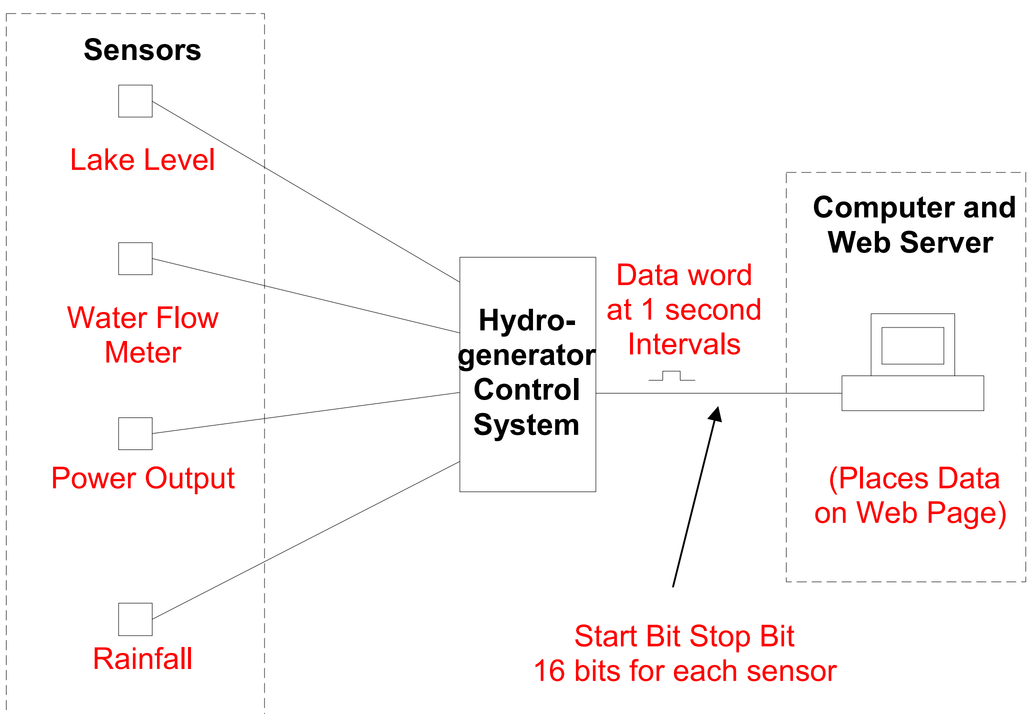

Figure 20: Data Acquisition System Schematic

Table 4: Location of Data Acquisition Sensors

Sensors	Type	Output	Location
Lake Level	Ultrasonic	4 – 20mA	On Lake Bank
Water Flow Rate	Flow Meter	4 – 20mA	In Penstock
Power Output	Electricity Meter	Pulse	On Generator Output
Rainfall	Rain Gauge	4 – 20mA	On top of dam

7.2 Web Server Prototype Page

From the hydro-generator control system the data collected from the sensors would be sent to a computer web server, located in the SLW&CA club house, at one second intervals. The data from the sensors would then be presented as live outputs of the system performance on an SLW&CA webpage. The web page should give the user the facility to access historical data.

A mock prototype of the proposed SLW&CA webpage is presented on the following page showing the real-time performance characteristics of the hydro scheme.

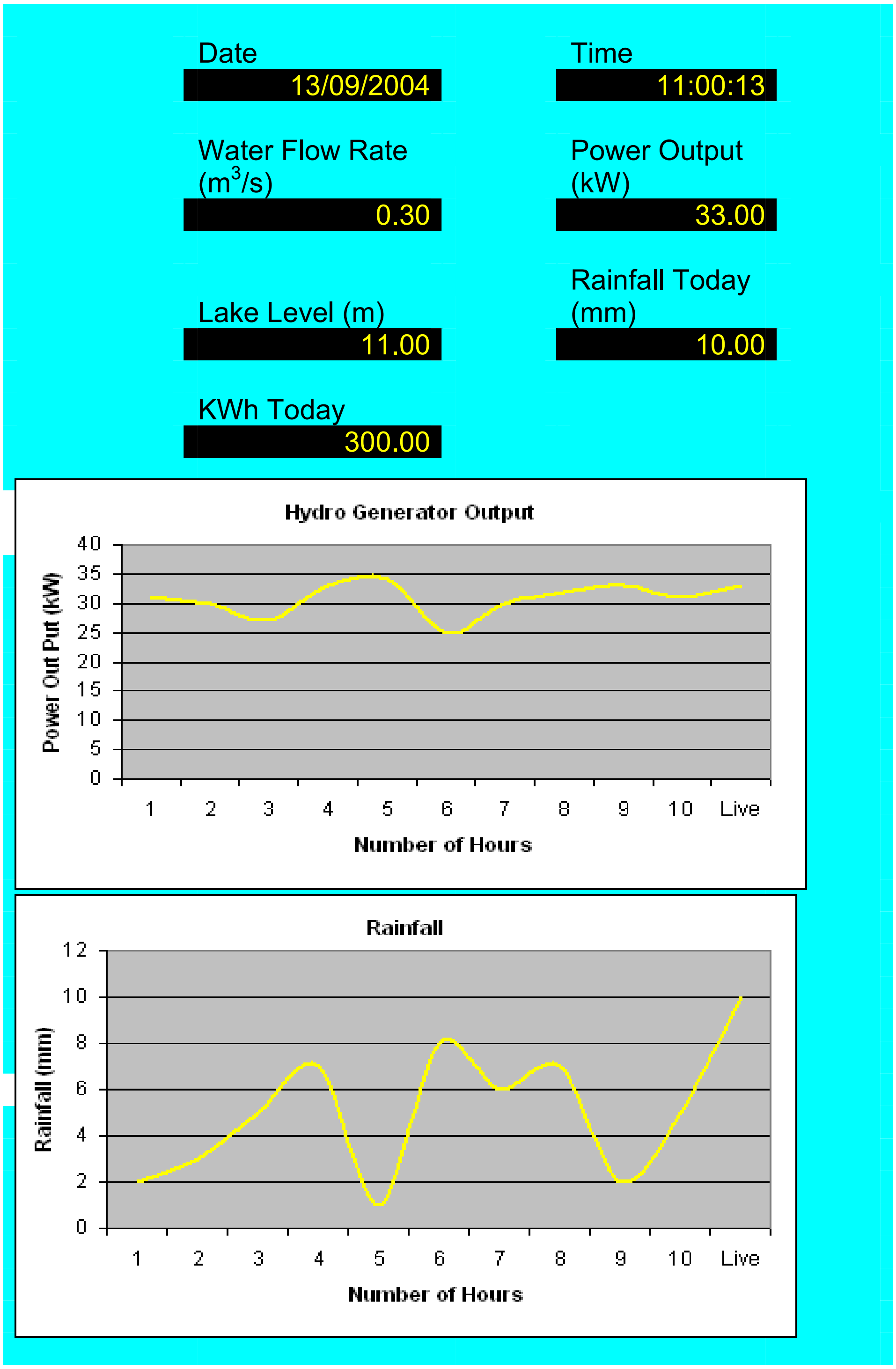

Figure 21 Prototype Web Page

Section V – Analysis of Potential Energy Resource and Income from Exported Energy

8.1 Methodology

A methodology was used to model the potential energy resource and income from exported energy from the proposed hydro-generator using the data gathered during the study. The feasibility study was constrained by time and limited availability of historical data. The study relies on flow rate measurements taken on two separate visits, one in winter and one in summer, and the Association's knowledge of hydrological and environmental aspects of the lake. The Association agree that the data, measured during the visits and over the course of the feasibility study, is an accurate representation of the lake's characteristics. This has permitted a technical analysis of different scenarios and a corresponding financial appraisal of the proposed micro-hydro scheme.

The methodology utilises CIBSE GUIDE VOLUME C Section C4 Flow of Fluids in Pipes Table C4.24 and Table C4.18 [1], and the Statement of Charges for Use of NIE plc Electricity and Distribution System [8]. The main objectives of the study are to establish the optimum location of the turbine-generator, the optimum diameter of penstock pipe and the income from exported energy. The location for the hydro-generator was identified in Section IV 6.10 Optimum Position for the Hydro-generator. Section V provides the methodology for examining the optimum pipe size and possible income generated by distributing the electricity generated across the network.

8.1.1 Site Survey

As no historical data is available, the site survey is essential for gathering flow rates, available head and possible locations of the hydro-generator. It is important to question the historical knowledge of the site, if there is any. A survey may also be able to identify electrical connection, planning and land ownership issues.

8.1.2 Penstock Pipe Size

As the existing pipe penstock cannot be re-used on the Glen Vale site, a technical analysis of the optimum pipe sizes must be undertaken. A spreadsheet (see Appendix D) with an array of flow rates was created, from the CIBSE GUIDE VOLUME C Section C4 Flow of Fluids in Pipes, for different diameter of pipes. Using the calculated optimum flow rates to maintain the lake's ecology, and available head at the site, the pressure losses in pipe sizes were established in order to calculate the effective head. From the effective head, flow rate and the turbine efficiency (using a Kaplan turbine), the power output was calculated and, hence, the optimum penstock pipe size identified.

8.1.3 Income from Electricity

To maximise the income from the hydro-generator, it is important that electricity output from the hydro-generator matches the electricity use profile of a customer in the area for a 24 hour period. However, it is highly unlikely that in any half-hour the exported electricity will exactly match the import requirements. In this case the deficit (makeup) will be made up by NIE Supply or another Supply business and charged under the Supply tariff (see Appendix C) [9]. Under the Bulk Purchase tariff the surplus (spill) will be purchased by NIE Power Procurement. NIE are keen to wheel distributed renewable sources of electricity over the network.

8.1.3.1 Distribution Use of System Charges

NIE Transmission & Distribution Business will apply Distribution Use of System charges to all units wheeled across the network. Distribution Use of System charges will be passed on to the embedded generator and are based upon the connected voltage and the appropriate Use of System tariff of the sites being wheeled to (see Appendix C).

8.1.3.2 NIE Electricity Tariffs

The study considers the distribution use of system charges, from the Statement of Charges for Use of the NIE plc Electricity Transmission and Distribution System and the associated consumer tariffs. Without considering domestic electricity supply, NIE's tariffs are subdivided into small commercial/ industrial and Seasonal Time of Day Tariff (STOD). The STOD tariff is further divided into two categories; Business and Farm Energy. The table in Appendix C shows all of the different tariffs available. However, the only tariffs analysed in conjunction with the operating hours of the hydro-generator are Farm and Business Energy for supplies under 1MW.

8.1.3.3 Connection Arrangement

The connection arrangement for generators wishing to export on to the NIE network includes a technical assessment of the connection arrangement at the property where the generator is to be located and can result in a charge for connecting the generator. A suitable meter 3 phase, Code 5, Issue 2 meter & modem will be required at a cost of £400 to record the import and export at each of the sites. A dedicated BT telephone line is also required for accessing and downloading the metering data on a daily basis.

8.1.4 Financial Viability

The final phase of the methodology was to assess the financial viability of the project. This includes all capital costs for the installation of a hydro-generator, associated electrical and civil works which were established from Newmills Hydro, located in Northern Ireland. Estimates of the annual costs are made and sources of finance for renewable projects.

8.2 Effective Head

The pressure losses in the pipe are a result of frictional drag and turbulence as the water flows through the pipe. These flow losses contribute towards energy losses in the system. The CIBSE GUIDE VOLUME C Section C4 Flow of Fluids in Pipes Table C4.24 and Table C4.18 were used to calculate pressure losses for a range of given flow rates for four different diameter pipes (300mm, 400mm, 450mm and 500mm). The calculations do not consider entry and exit losses from different pipe diameters because they are negligible for pipes of these diameters. For each pipe diameter the calculation was based, firstly, on a 14.2m available head and 150m pipe length and, secondly, on a 17m available head and 260m pipe length. The pressure loss of the pipe is taken away from the available head to give the effective head for different flow rates. The potential power output is calculated for each of the different values for effective head and corresponding flow rate. There are further energy losses converting the input power into electrical output. The calculations assume a hydro-generator efficiency of 90% and is based on a Kaplan vertical axis turbine. Power and flow rate line graphs were produced against an effective head, for locations one and two, for different pipe diameters.

Figure 22 shows the power output from a 500mm diameter pipe with the hydro-generator situated in location 1, with 15m available head and 150m pipe length. The effective head is increased with a 500mm pipe compared to other diameter pipes as the pressure losses and flow rate are reduced. The power output with a 500mm pipe shows a more linear trend than with lower pipe diameter sizes, giving 54kW peak output at 0.5m^3/s. The graph shows that the power output increases as the flowrate increases while the effective head decreases. If the flowrate is increased in a given pipe this causes increased pressure losses as a result and, hence, the effective head is reduced. Although the effective head is reduced in Figure 22 below, the flowrate increases sufficiently to result in an increase in power. However, there are cases (see Appendix A Figure 27) where the flowrate in the pipe becomes so high that the pressure losses result in a significant reduction in effective head, causing the power output to decrease. A number of similar graphs were produced for the hydro-generator sited at location 1 and two for different pipe diameters. However, siting the hydro-generator at location 1 (14.2m actual head), with a 500mm diameter pipe was found to be the optimum location and pipe size for the hydro-generator. See Appendix A for the power output analysis of different pipe diameters at an available head of 14.2m and 17m.

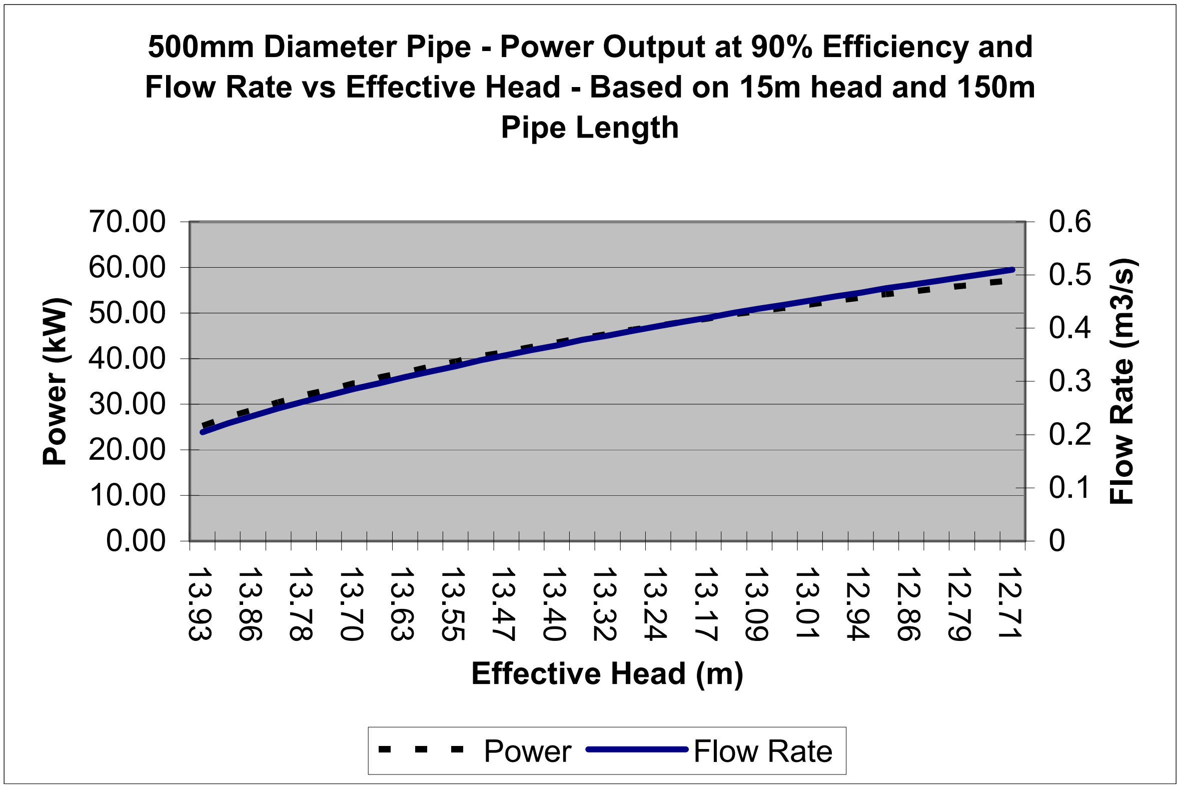

Figure 22: Power Output from a 500mm Diameter Pipe

8.3 Electricity Consumers

The site has one small building, the clubhouse, which is occasionally used and which uses electricity for lighting and domestic appliances only. Hence, there is no significant electrical load on the site. The electricity generated by the proposed hydro scheme could be sold to a consumer in the area, with a load which matches the proposed hydro-generator output or to NIE.

The preferred option would be to sell to a consumer in the area. For SLW&CA to maximise their income they need a customer whose electricity use profile matches the output of the proposed hydro-generator, uses electricity 24 hours a day and pays an average commercial or industrial tariff and a Seasonal Time of Day (SToD) charge. The NIE SToD tariff is a charge levied on commercial and industrial consumers for 3 hours per day in Northern Ireland between November and February and can be 45p/kWh or more.

It is therefore necessary to identify a nominated recipient and wheel electricity over the Northern Ireland Electricity (NIE) Network. NIE would charge SLW&CA for using distribution lines (wheeling) at around 2.5p/kWh.

8.4 Proposed Turbine Operating Schedule

The different tariff structures provided by NIE must be considered in conjunction with the turbine operating under conditions that will not adversely affect the ecology of the lake. The proposed operational schedule for the hydro scheme is assumed purely for the feasibility analysis. To optimise the income whilst maintaining an acceptable lake level, the following operation should be adopted for supplying electricity to the grid or a nominated recipient:

1. Operate the turbine at a flow rate of 0.22m^3/s (44% flow, 78.1% system efficiency and 14.69m effective head on a 500mm penstock) for the following periods of the year:

    - March & October 0800-2030 hours (weekdays)
    - March & October 2030-2230 hours (weekday Evenings)
    - March & October 2230-0800 hours (weekday Nights)
    - March & October (weekends)
    - November - February (weekends)

2. Operate the turbine at a lower flow rate of 0.17m^3/s (34% flow, 76.24% system efficiency and 14.81m effective head on a 500mm penstock) for the periods described below:

    - November & February (weekday outside SToD hours)
    - January & December (weekday)

3. Operate the turbine at the peak flow rate of $0.5m^3/s$ (100% flow, 85.5% system efficiency and 13.55m effective head on a 500mm penstock) for the period described below:

    - November - February (SToD 1600 -1900 hours)

4. Operate the turbine at the peak flow rate of $0.15m^3/s$ (30% flow, 75.5% system efficiency and 14.85m effective head on a 500mm penstock) for the period described below:

    - April – September 6.7hours between 0800 – 2030 Weekdays

8.5 Analysis of Potential Revenue Resulting from Selling Electricity

The calculations in this section are based on a Kaplan Turbine with a maximum

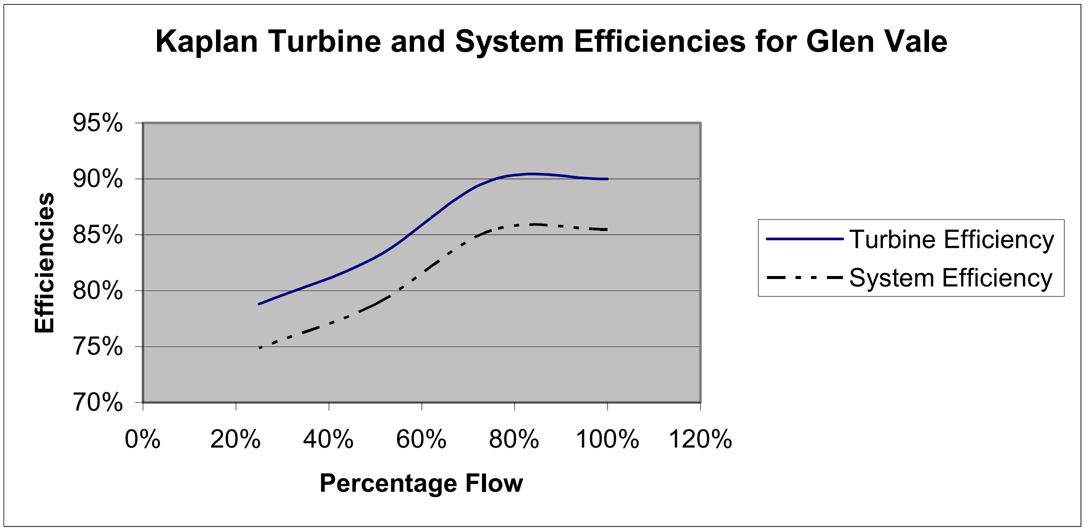

Figure 23: Kaplan Turbine and System Efficiencies for Glen Vale

output of 54kW designed for the Glen Vale site. The graph above shows that the turbine efficiency is 92% at a maximum flow rate. The turbine efficiency curve in Figure 23 was extrapolated from the Kaplan turbine efficiency graph from Newmills Hydro (see Figure 11). The system efficiency is based on an assumed generator efficiency of 95% and the corresponding turbine efficiency at a given flow rate.

Appendix C shows the standard electricity tariffs for NIE for supplies greater or less than 1MW and whether the supply is on a high voltage or medium voltage line. For the purposes of the case study an analysis of the possible incomes was undertaken for supplies of less than 1MW on the Business Multi-Option and Farm Tariffs. The full analysis can be seen in the tables in Appendix D. The following tables are a summary of the results in Appendix D:

Table 5: Revenues for Different Pipe Diameters with Business Tariff Multi-Rate Option Under 1MW High Voltage Line with the Hydro-generator Sited at a 15m Head

Diameter of Pipe (mm)	Annual Energy (kWh)	Revenue (£)
400mm	116,085	£10,132
450mm	119,500	£10,523
500mm	120,677	£11,505

Table 6: Revenues for Different Pipe Diameters Farm Tariff Multi-Rate Option Under 1MW High Voltage Line with the Hydro-generator Sited at a 15m Head

Diameter of Pipe (mm)	Annual Energy (kWh)	Revenue (£)
400mm	116,085	£9,679
450mm	119,500	£10,044
500mm	120,677	£10,972

The two tables clearly show that the 500mm pipe provides the greatest annual revenue for the SLW&CA. A comparison between the figures in the two tables also shows that the Business Tariff provides the greatest income of the two tariffs.

8.6 Analysis of Potential Revenue Resulting from Selling Electricity to Exploris

SLW&CA approached Ards Borough Council for assistance with a micro-hydro feasibility study. The Council proposed that SLW&CA could sell the electricity generated by the proposed hydro-generator to Exploris. The Exploris building is on the Farm Energy NIE tariff.

The table below shows the distribution use of system charges if SLW&CA were to wheel electricity to Exploris.

Table 7: Distributed Use of System Charges for Exploris

Distribution UoS Charges in Respect of Wheeled Units[4]							
STOD TARIFFS	**Peak**		**Weekday**		**Day units April – Oct & March**	**Evening & Weekend**	**Night**
	Dec/Jan p/kWh	**Nov/Feb p/kWh**	**Dec/Jan p/kWh**	**Nov/Feb p/kWh**	**p/kWh**	**p/kWh**	**p/kWh**
Medium Voltage							
under 1 MW	12.671	11.872	2.760	1.379	0.476	0.545	0.226

For the purpose of the study, and in order to calculate the possible revenue available to the association, the Council provided the current unit charges of electricity for Exploris. The table on the following page shows the different NIE tariff structures for Exploris and establishes the unit income for SLW&CA if they were to sell electricity to the Council.

[4] Table 5 is taken from Schedule E Table 1b from the Statement of Charges for Use of The Northern Ireland Electricity and Distribution System by Authorised Persons provided by NIE

The annual energy resource available and income revenue from Exploris are shown in the table below for a given power output and flowrate.

Table 8: Unit Electricity income for SLW&CA

Exploris Tariff Structure	Exploris Tariff p/kWh	NIE Wheeling Charge p/kWh	Unit Income for SLW&CA p/kWh
April - October & March 0800-2030 hours (weekdays)	6.4	0.476	5.924
April - October & March 2030-2230 hours (weekday Evenings)	3.5	0.545	2.955
April - October & March 2230-0800 hours (weekday Nights)	3.5	0.226	3.274
April - October & March (weekends)	3.5	0.545	2.955
Nov & Feb (weekday Outside SToD hours	9.6	1.379	8.221
Jan & Dec (weekday)	9.6	2.76	6.84
Nov & Feb (SToD 1600-1900 hours)	48	11.872	36.128
Jan & Dec (SToD 1600-1900 hours)	48	12.671	35.329
Nov & Feb (weekends)	3.5	0.545	2.955
Jan & Dec (weekends)	3.5	0.545	2.955

8.7 Energy Resource and Projected Income

Estimates of the annual energy resource available and income revenue from Exploris are shown in the table below. The same calculations were undertaken for another hydro-generator location on the site and different diameters of pipes. However, the data in the table are estimates of the annual energy resource available and income revenue for the hydro-generator at the optimum location, ie Location 9, with a 15m actual head.

Table 9: Annual Energy Resource and Income from Exploris

	500mm Diameter Pipe – 15m Actual Head		
Exploris Tariff Structure	**Power Output (kW)**	**Annual Energy (kWh)**	**Annual Revenue (£)**
March & October 0800-2030 hours (weekdays)	24.88	13,684	£811
March & October 2030-2230 hours (weekday Evenings)	24.88	2,189	£65
March & October 2230-0800 hours (weekday Nights)	24.88	10,400	£340
March & October (weekends)	24.88	10,748	£318
Nov & Feb (weekday Outside SToD hours)	18.81	16,591	£1,364
Jan & Dec (weekday)	18.81	17,776	£1,216
Nov & Feb (SToD 1600-1900 hours)	57.16	7,202	£2,602
Jan & Dec (SToD 1600-1900 hours)	57.16	7,717	£2,726
Nov & Feb (weekends)	24.88	19,705	£582
April - September between 0800-20 hours weekdays	16.71	14,466	£857
Total		120,677	£10,892

If SLW&CA were to supply Exploris, and the hydro-generator were installed at Location 9 with a 500mm diameter pipe supplying water to a Kaplan turbine a revenue of £10,892 per annum could be possible.

Section VI - Financial Viability

9.1 Capital Costs

An analysis of estimated costs for the proposed hydro project is given in this section. The hydro contractor costs are accurate costs received as a result of a tendering process in support of the feasibility study. The costs include:

- Civil, mechanical and electrical works
- System design
- Supply of all plant and equipment
- Installation, Connection, Testing and commissioning of Plant and Equipment
- Provisional Sums for:
  - Connection to the NIE system
  - Repairs to the upstream silt traps
  - Upgrades to the outflow stream
  - Installation of an automatic level controlled weir on the lower pond
  - Planning costs and other statutory fees
  - Project Management costs
  - A web server and broadband connection

Total estimated costs = £267,951

9.2 Ongoing Annual Costs

Estimates of ongoing costs are:

- Operation and Maintenance Contract for hydro-generator = £750
- Annual rental of broadband circuit for web server = £200
- Website maintenance = £200
- Insurance = £500

Total ongoing costs = £1,650 / annum

9.3 Sources of Finance

The financing plan for the project is:

1. Clear Skies grant of 50% of project cost = £100,000
2. Northern Ireland Electricity SMART fund of 25% of project cost = £64,488
3. The balance of funding to come from:

   Ards Borough Council Local Agenda 21 Committee funding

   Funds raised by the Association

The Association is investigating several options for raising the balance of funding required. These could include loans from members and membership levies, and an interest free loan from the British Association of Shooting Clubs. The club's property portfolio is estimated to be worth up to £1,000,000, and further finance could be raised through the sale of a portion of the Glen Vale site which could raise up to £100,000.

9.4 Annual Income for SLW&CA

The annual income from the hydro-generator, based on a 90% peak efficiency Kaplan Turbine installation, could be £10,800 per annum. The analysis of annual energy resource and income from exported energy, Appendix D, covers the projected performance of all components of installation including energy, rating/output (kW, kWh/year). The sale by subscription of hydro system data over the internet could produce a small income helping to offset the cost of operating the web server. The data could be of interest to students or people installing their own micro-hydro systems and, hence, fees could be charged at £1 each time the data the data is accessed. This could provide a small annual income contributing towards the cost of maintaining the web page. In future years, when at least one year's worth of data has been collected and the site is known worldwide, it is hoped that sufficient income would be produced to cover the whole of the web server operating costs. An estimate of the net annual income available is £9,150.

The table below is a summary of the hydro installation costs at the Glen Vale site. These costs were provided by Newmills Hydro.

Table 10: Summary of Capital Costs and Funding

	Capital Costs	**Clearskies Grant**	**NIE SMART Funding**	**Balance Required**
Hydro Contractor	£179,951			
NIE Connection to Grid	£45,000			
Planning Permission	£2,000			
Project Management	£15,000			
Outflow Upgrades	£10,000			
Automatic weir	£10,000			
Repair Silt traps	£2,000			
Webserver/website	£4,000			
Total	**£267,951**	**£100,000**	**£66,988**	**£100,963**

9.5 Renewable Obligation Certificates (ROCs)

The renewable obligation directs electricity companies to source a proportion of their generating capacity from renewable technologies, and was introduced by the government to stimulate investment in renewable energy. ROCs are awarded to accredited generators of eligible renewable electricity produced within the UK. Types of renewable technologies that are eligible are; solar energy, hydro, wave power, tidal energy, geothermal energy, biofuels and on and offshore wind farms.

At the time of the meeting with Stephen Thompson of NIE he was asked for guidance on ROCs. Stephen was unable to help at that time, or give us a contact with whom we could discuss ROCs, as he stated that no decisions had yet been made about ROCs in Northern Ireland and that no information had yet been published. Following a telephone conversation with Jenny

Boyd, Malachy Mckernon of the DETI Energy Division was contacted. He advised that he is currently preparing a consultation document in which it is proposed that small scale hydro (less than 1.25MW capacity) in Northern Ireland be eligible for ROCs from April 2005. It is therefore, highly likely that the proposed hydro system will be eligible, but is not a foregone conclusion. Based on the current value of 4p/kWh (this could change), the estimated 120,000kWh of electricity generated annually by the system could attract an additional annual income of £4,800. This would increase the net annual income from £9,150 in the feasibility study to £13,950. It should be noted that as ROCs are a tradeable commodity their value is not fixed and can rise or fall dependent on market forces.

Section VII – Conclusions and Recommendations

10.1 Conclusions

The approach undertaken in this thesis involved five stages which are summarised below.

<u>Stage 1</u>

A literature review of hydro-electricity aided in providing an understanding of hydro schemes, their components and the requirements to perform a field study at the Glen Vale site. The main findings were that the majority of micro-hydro installations in the UK were installed before 1990, relating to the textile industry, and not grid connected. To connect the proposed SLW&CA turbine generator to the grid strict health and safety guidelines must be followed and, to reduce the strain on the electricity network a local load matching the output from the generator must be found. The literature review established that no real-time performance data from the web is available from any micro-hydro installation.

<u>Stage 2</u>

The feasibility study itself, because of time constraints, permitted flow rate measurements from the existing outflow to be taken on two separate occasions with the Association's Chairman recording overspill measurements throughout the winter. Using a theodolite, possible generator locations were established to maximize the available head. The findings resulted in a peak power output of 54kW. A Kaplan turbine, the most efficient turbine at the available head and flow rate, was selected from the findings in the literature review. The knowledge from the Association and Council was used to determine the environmental and socio-economic impacts of the proposed hydro scheme.

<u>Stage 3</u>

Hydro installers were contacted to establish indicative installation costs of a 56kW turbine.

Stage 4

A sustainable operating schedule for the micro-hydro scheme was assumed based on sustainable flow rates and maximising possible income from NIE tariffs and use of system distribution charges.

Stage 5

Using the costs provided by a hydro installer, the predicted income from the hydro-generator, and possible grants, the proposed scheme was found to have a payback of just over 10 years.

Without grant assistance the payback on the micro-hydro scheme would be over 28 years. This length of payback is typical for capital intensive hydro installations. However, the installation is financially viable if viewed long term by the Association, with a payback of 10 years which could be less if the cost of electricity increases.

The five stage approach used in the thesis to assess the feasibility of a micro-hydro installation could be used as a guideline methodology for other projects of a similar size and nature. However, stage two of the methodology would need to be adapted if there was no existing sustainable outflow from the lake. Water levels, rainfall analysis and catchment area would have to be taken into account in the survey of the site. An analysis of the impact on lake level by alternating the water flow rate throughout the seasons would be required. The electricity tariffs would have to be analysed, based on the different suppliers for a given location.

10.2 Recommendations

It is recommended that if grant funding is made available that the Association employ a hydro contractor to install the micro-hydro turbine scheme described in this thesis. As part of the installation the Association should ensure that the installer agrees with all measurements and assumptions made in this thesis. Further work is required to produce a detailed schematic of the data acquisition system and web page with performance characteristics of the scheme.

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APPENDICES

Appendix A - Pipe Pressure Loss

It was initially predicted that, before measurements were taken, the flow rate would be of the order of 0.5m^3/s, giving a power output of 49kW (before efficiency of the generator is taken into account) on an available head of 10m. However, the measured flow rate of 0.12m^3/s (3.9m/s) from the valve house outlet on full flow did not match the prediction as the theoretical power output from the measured flow rate would be 11.8kW (37.2kW lower than expected).

Equating the kinetic energy in the measured flow to the potential energy required to produce that flow, the head for the measured velocity of water flowing at 3.9m/s was calculated as 0.76m. As the actual head is 10m, 92% of the potential energy available is lost as pipe friction loss.

The explanations for the pressure losses are a combination of three factors. The first is that the pipe is cast iron and was installed around 90 years ago. It is therefore suspected from the condition of the pipes in the valve house (see Figure 24 below) to have been subjected to corrosion, causing turbulent flow in the pipes and increasing the pressure loss. The second issue is that the inlet from the lake is 40m from the dam and could be a further 15m to 20m before existing at the

Figure 24: Valve House Pipework

outlet from the valve house, resulting in significant pressure loss over this distance. The third combining factor is the lake has gathered silt over time, which the SLW & CA have expressed increasing problems with. It is suspected that the existing intake pipe could be clogged. This assumption is further verified by the substantial rotted leaf debris which collected on and fouled the measuring equipment during the survey. To optimise the performance of the system it is recommended that that the existing pipe be abandoned and be permanently valved off as the power available from the existing pipe is too small for practical purposes.

Effective Head

The CIBSE GUIDE VOLUME C Section C4 Flow of Fluids in Pipes Table C4.24 and Table C4.18 were used to calculate pressure losses for a range of given flow rates for four different diameter pipes (300mm, 400mm, 450mm and 500mm). The graphs are discussed and shown on the following page.

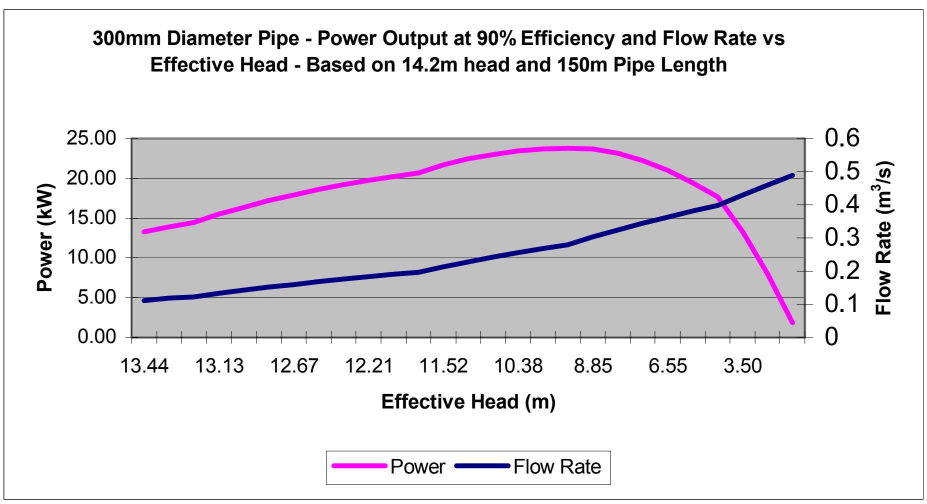

Figure 25: Power Output from a 300mm Diameter Pipe with the Hydro-generator Situated in Location 1

Figure 25 shows the power output from a 300mm diameter pipe with the hydro-generator situated in location 1, with 14.2m available head and a 150m pipe length. The graph shows that the peak power output could be around 23kW for a corresponding flowrate of around 0.3m^3/s and an effective head of around 9m.

The pressure losses become so great once the flow rate reaches a certain point (in this case around 0.35m^3/s) that the power falls significantly.

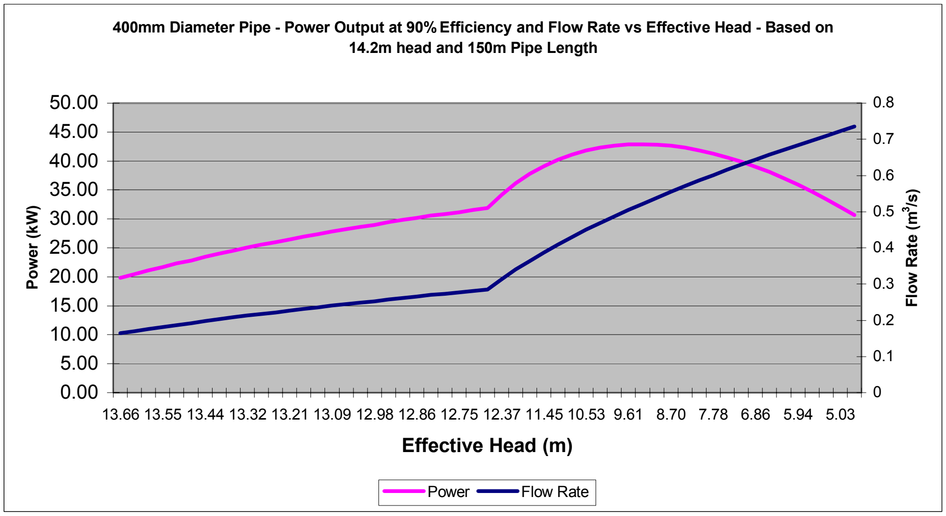

Figure 26: Power Output from a 400mm Diameter Pipe with the Hydro-generator Situated in Location 1

Figure 26 shows the power output from a 400mm diameter pipe with the hydro-generator situated in location 1, with 14.2m available head and 150m pipe length. This scenario could generate a peak power output of around 42kW with a flow rate of the order of 0.52m^3/s and an effective head of around 9m. Figure 26 shows a similar trend to Figure 25 with the power falling once the flow rate reaches around 0.55m^3/s[5].

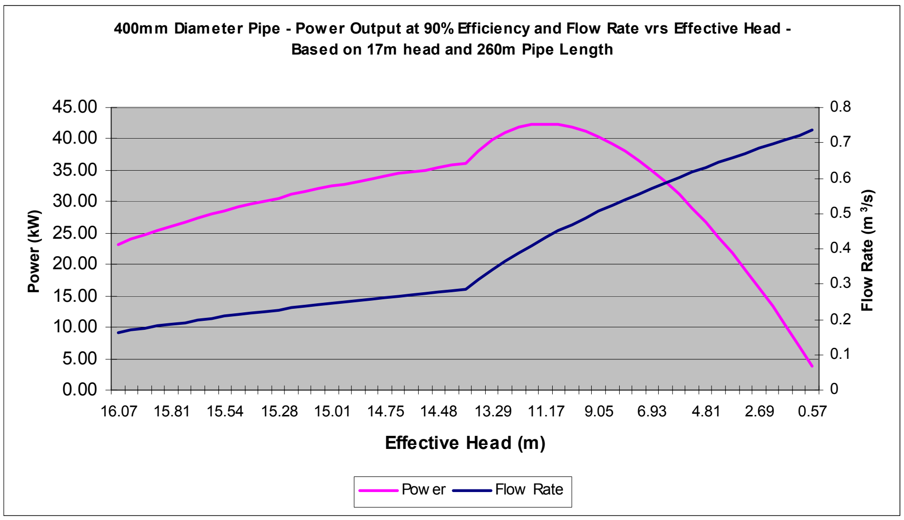

Figure 27: Power Output from a 400mm Diameter Pipe with the Hydro-generator Situated in Location 2

Figure 27 shows the power output from a 400mm diameter pipe with the hydro-generator situated in location 2, with 17m available head and 260m pipe length. A comparison between situating the generator at location 1 and 2 shows that the average power increases slightly for different flow rates if positioned in location 2. However, the peak power generated by location 2 would be the same as location 1, but would require an even greater flow rate.

[5] The apparent cusp in the flow rate and power output curves in graph 2, 3 and 4 result from the CIBSE data used in the calculations.

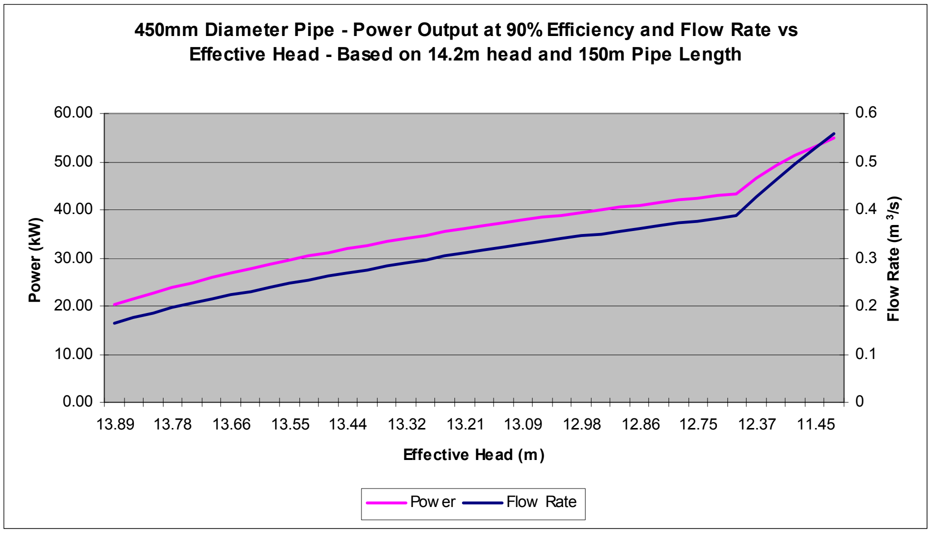

Figure 28: Power Output from a 450mm Diameter Pipe with the Hydro-generator Situated in Location 1

Figure 28 shows the power output from a 450mm diameter pipe with the hydro-generator situated in location 1, with 14.2m available head and 150m pipe length. It can be seen that with generally lower flow rates than a 400mm pipe (see Figure 25) the power increases by, on average, 4kW. The pressure losses are also reduced compared to Figure 26. The peak power output that could be generated would be of the order of 54kW for a flow rate of around 0.55m^3/s.

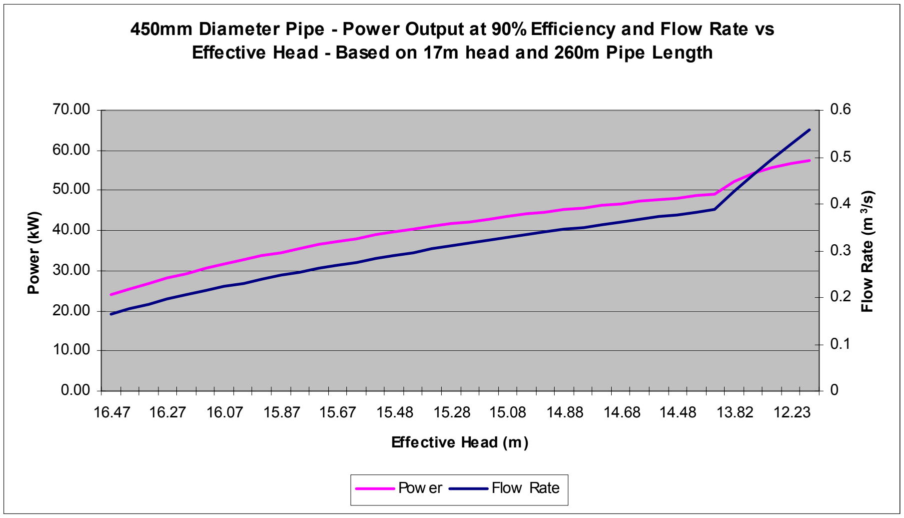

Figure 29: Power Output from a 450mm Diameter Pipe with the Hydro-generator Situated in Location 2

Figure 29 shows the power output from a 450mm diameter pipe with the hydro-generator situated in location 2, with 17m available head and 260m pipe length. By moving the generator to location 2 with a 450mm pipe, Figure 29 shows that the power output is only likely to increase by around 3kW from positioning a 450mm pipe in location 1 (see Figure 26).

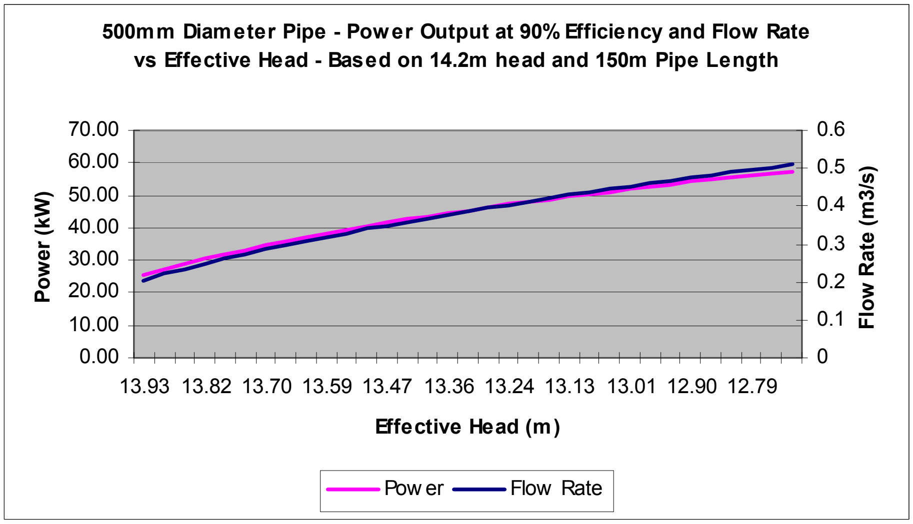

Figure 30: Power Output from a 450mm Diameter Pipe with the Hydro-generator Situated in Location 1

Figure 30 shows the power output from a 450mm diameter pipe with the hydro-generator situated in location 1, with 14.2m available head and 150m pipe length. The effective head is increased with a 500mm pipe compared to a 450mm pipe (see Figure 28) as the pressure losses and flow rate are reduced. The power output with a 500mm pipe shows a more linear trend and an average increase of around 4kW over the 450mm pipe for the same hydro-generator location (see Figure 28), giving 58kW peak at $0.5m^3/s$.

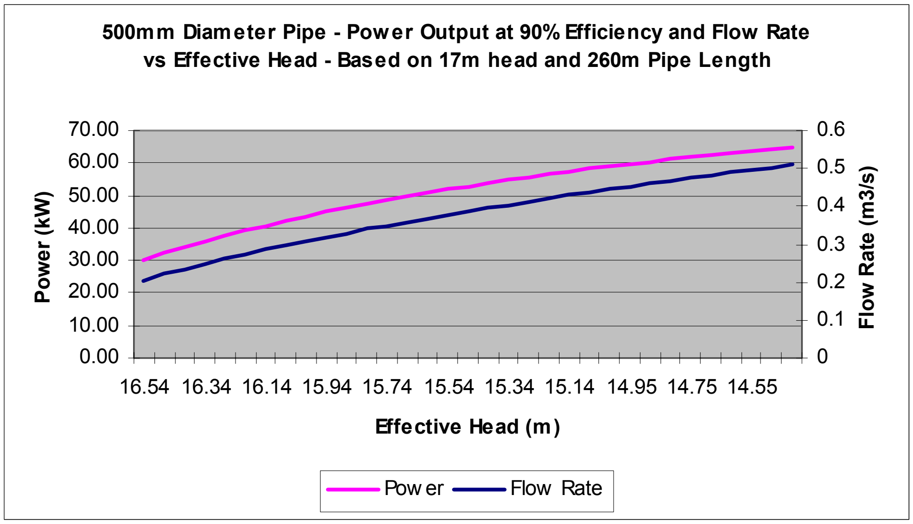

Figure 31: Power Output from a 450mm Diameter Pipe with the Hydro-generator Situated in Location 2

Figure 31 shows the power output from a 500mm diameter pipe with the hydro-generator situated in location 2, with 17m available head and 260m pipe length. By moving the generator to location 2 with a 500mm pipe, Figure 31 shows that the power output could increase by around 7kW from positioning a 500mm pipe in location 1 (see Figure 30), giving 65kW peak at 0.5m^3/s.

Appendix B – Contacts

Northern Ireland Electricity

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Appendix C – Northern Ireland Electricity Tariffs

Table 11: NIE Tariff Structure and Distributed Use of System Charges

			NIE Wheeling Charge (p/kWh)			
		Tariff (p/kWh)	**Small Commercial/ Industrial (p/kWh)**	**Small Commercial/Industrial Economy 7 (Preserved) (p/kWh)**	**Small Commercial/Industrial Economy 7 (p/kWh)**	**STOD Tariff (p/kWh)**
Popular Option		9.2	1.816			
Night Saver Option	Daytime (8am-1am)	9.8		1.988	1.975	
	Night time & Heating Unit Rate (1am-8am)	3.3		0.287	0.284	
Weekender Option	Daytime (Mon-Fri, 7-30am-8pm)	12		2.863		
	Evening and Weekend (Mon-Fri 8pm-7-30am)	4.75		0.489		
Farm Energy Popular Option	Daytime Unit (8am - 1am)	9.08	1.816			
Farm Energy Night Saver	Daytime Unit (8am - 1am)	9.3		1.988		
	Night Time Unit (1am-8am	3.3		0.287		
Multi Rate Options (Medium Voltage) Under 1MW	Winter Peak (Mon-Fri 4pm-7pm Nov and Feb	48				12.671
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	48				12.671
	Winter Daytime Nov + Feb (Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.3				1.379
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.3				2.76
	Summer Daytime (Mon-Fri, 8am -830pm)	6.5				0.476
	Summer Night time (Mon-Fri, 2230 - 0800)	6.5				0.226
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	4.3				0.545

Multi Rate Option (Medium Voltage) Over 1MW Average Distance	Winter Peak (Mon-Fri 4pm-7pm Nov and Feb	48				11.702
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	48				11.722
	Winter Daytime Nov + Feb (Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.3				1.1
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.3				2.247
	Summer Daytime (Mon-Fri, 8am -830pm)	6.5				0.374
	Summer Night time (Mon-Fri, 2230 - 0800)	6.5				0.205
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	4.3				0.426
Multi Rate Option (Medium Voltage) Over 1MW Minimum Distance	Winter Peak (Mon-Fri 4pm-7pm Nov and Feb	48				9.441
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	48				10.657
	Winter Daytime Nov + Feb (Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.3				0.948
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.3				1.923
	Summer Daytime (Mon-Fri, 8am -830pm)	6.5				0.286
	Summer Night time (Mon-Fri, 2230 - 0800)	6.5				0.154
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	4.3				0.426
Multi Rate Option (High Voltage) Under 1MW	Winter Peak (Mon-Fri 4pm-7pm Nov and Feb	45				5.205
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	45				5.611
	Winter Daytime Nov + Feb (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.7				0.888
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.7				1.95
	Summer Daytime (Mon-Fri, 8am -830pm)	6				0.257
	Summer Night time (Mon-Fri, 2230 - 0800)	6				0.155
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	3.7				0.308

Multi Rate Option (High Voltage) Over 1MW Average Distance	Winter Peak (Mon-Fri 4pm-7pm Nov and Feb	45				7.314
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	45				7.945
	Winter Daytime Nov + Feb (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.7				0.932
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.7				1.898
	Summer Daytime (Mon-Fri, 8am -830pm)	6				0.256
	Summer Night time (Mon-Fri, 2230 - 0800)	6				0.123
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	3.7				0.298
Multi Rate Option (High Voltage) Over 1MW Minimum Distance	Winter Peak (Mon-Fri 4pm-7pm Nov and Feb	45				3.243
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	45				2.29
	Winter Daytime Nov + Feb (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.7				0.748
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.7				1.443
	Summer Daytime (Mon-Fri, 8am -830pm)	6				0.172
	Summer Night time (Mon-Fri, 2230 - 0800)	6				0.075
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	3.7				0.212
Farm Energy						
Multi Rate Options (med Voltage) Under 1MW	Winter Peak (Mon-Fri 4pm-7pm) Nov and Feb	48				11.872
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	48				12.671
	Winter Daytime Nov + Feb(Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.6				1.379
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.6				2.76
	Summer Daytime (Mon-Fri, 8am -830pm)	6.4				0.476
	Summer Night time (Mon-Fri, 2230 - 0800)	3.5				0.226
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	3.5				0.545

Multi Rate Options (med Volatge) Over 1MW Average Distance	Winter Peak (Mon-Fri 4pm-7pm) Nov and Feb	48				11.702
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	48				11.722
	Winter Daytime Nov + Feb(Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.6				1.1
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.6				2.247
	Summer Daytime (Mon-Fri, 8am -830pm)	6.4				0.374
	Summer Night time (Mon-Fri, 2230 - 0800)	3.5				0.205
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	3.5				0.426
Multi Rate Options (med Volatge) Over 1MW Minimum Distance	Winter Peak (Mon-Fri 4pm-7pm) Nov and Feb	48				9.441
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	48				10.657
	Winter Daytime Nov + Feb(Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.6				0.948
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	9.6				1.923
	Summer Daytime (Mon-Fri, 8am -830pm)	6.4				0.286
	Summer Night time (Mon-Fri, 2230 - 0800)	3.5				0.154
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	3.5				0.426
Multi Rate Option (high Voltage) Under 1MW	Winter Peak (Mon-Fri 4pm-7pm Nov and Feb	43				5.205
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	43				5.611
	Winter Daytime Nov + Feb (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.6				0.888
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.6				1.95
	Summer Daytime (Mon-Fri, 8am -830pm)	5.9				0.257
	Summer Night time (Mon-Fri, 2230 - 0800)	5.9				0.155
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	3.3				0.308

Multi Rate Option (high Voltage) Over 1MW Average Distance	Winter Peak (Mon-Fri 4pm-7pm Nov and Feb	43				7.314
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	43				7.945
	Winter Daytime Nov + Feb (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.6				0.932
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.6				1.898
	Summer Daytime (Mon-Fri, 8am -830pm)	5.9				0.256
	Summer Night time (Mon-Fri, 2230 - 0800)	5.9				0.123
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	3.3				0.298
Multi Rate Option (high Voltage) Over 1MW Minimum Distance	Winter Peak (Mon-Fri 4pm-7pm Nov and Feb	43				3.243
	Winter Peak (Mon-Fri 4pm-7pm) Jan and Dec	43				2.29
	Winter Daytime Nov + Feb (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.6				0.748
	Winter Daytime Jan & Dec (Mon-Fir, 8am-830pm excluding Winter Peak Times)	8.6				1.443
	Summer Daytime (Mon-Fri, 8am -830pm)	5.9				0.172
	Summer Night time (Mon-Fri, 2230 - 0800)	5.9				0.075
	Evening and weekend (all year Mon-Fri, 830pm-8am and weekend)	3.3				0.212

Appendix D – Power Outputs for Different Pipe Lengths and Diameters and Flow Rates

Table 12: Power Output from 150m Length of 500mm Diameter Pipe at a 15m Head

Note: The figures highlighted in yellow (in all of the tables in Appendix D) are the flow rates which will maintain the ecology of the lake during certain periods of the year.

	Mass Flow Rate (kg/s)	Delta P Pipe (kPa/m)	Delta P(kPa)	Delta P (m)	Head (m)	Effective Head (m)	44% Flow Power at 78.1% System Efficiency (kW)	34% Flow Power at 76.24% system Efficiency(kW)	100%flow Power at 85.5% system Efficiency (kW)	30% Flow Power at 75.5% system Efficiency (kW)
	144	0.009	1.35	0.14	15.00	14.86	16.40	16.01	17.95	15.85
	148	0.0095	1.425	0.15	15.00	14.85	16.84	16.44	18.44	16.28
Nov & Feb STOD	152	0.01	1.5	0.15	15.00	14.85	17.29	16.88	18.93	16.71
Jan & Dec weekends	172	0.0125	1.875	0.19	15.00	14.81	19.52	19.05	21.36	18.87
	189	0.015	2.25	0.23	15.00	14.77	21.39	20.88	23.42	20.68
	205	0.0175	2.625	0.27	15.00	14.73	23.14	22.59	25.33	22.37
Sustainable Flow Rate	221	0.02	3	0.31	15.00	14.69	24.88	24.29	27.24	24.05
	235	0.0225	3.375	0.34	15.00	14.66	26.39	25.76	28.89	25.51
	249	0.025	3.75	0.38	15.00	14.62	27.89	27.22	30.53	26.96
	262	0.0275	4.125	0.42	15.00	14.58	29.27	28.57	32.04	28.29
	274	0.03	4.5	0.46	15.00	14.54	30.53	29.80	33.42	29.51
	286	0.0325	4.875	0.50	15.00	14.50	31.78	31.02	34.79	30.72
	297	0.035	5.25	0.54	15.00	14.46	32.91	32.13	36.03	31.82
	308	0.0375	5.625	0.57	15.00	14.43	34.04	33.23	37.27	32.91
	319	0.04	6	0.61	15.00	14.39	35.17	34.33	38.50	34.00
	329	0.0425	6.375	0.65	15.00	14.35	36.17	35.31	39.60	34.97
	340	0.045	6.75	0.69	15.00	14.31	37.28	36.39	40.81	36.04
	349	0.0475	7.125	0.73	15.00	14.27	38.17	37.26	41.78	36.90
	359	0.05	7.5	0.76	15.00	14.24	39.15	38.22	42.86	37.85
	368	0.0525	7.875	0.80	15.00	14.20	40.03	39.08	43.82	38.70
	378	0.055	8.25	0.84	15.00	14.16	41.01	40.03	44.89	39.64
	386	0.0575	8.625	0.88	15.00	14.12	41.76	40.77	45.72	40.37
	395	0.06	9	0.92	15.00	14.08	42.62	41.60	46.66	41.20

	404	0.0625	9.375	0.96	15.00	14.04	43.47	42.44	47.59	42.02
	412	0.065	9.75	0.99	15.00	14.01	44.21	43.16	48.40	42.74
	420	0.0675	10.125	1.03	15.00	13.97	44.95	43.88	49.21	43.45
	429	0.07	10.5	1.07	15.00	13.93	45.78	44.69	50.12	44.26
	437	0.0725	10.875	1.11	15.00	13.89	46.51	45.40	50.92	44.96
	444	0.075	11.25	1.15	15.00	13.85	47.13	46.00	51.59	45.56
	452	0.0775	11.625	1.19	15.00	13.81	47.84	46.70	52.37	46.25
	460	0.08	12	1.22	15.00	13.78	48.55	47.40	53.15	46.94
	467	0.0825	12.375	1.26	15.00	13.74	49.16	47.99	53.81	47.52
	475	0.085	12.75	1.30	15.00	13.70	49.86	48.67	54.58	48.20
	482	0.0875	13.125	1.34	15.00	13.66	50.45	49.25	55.23	48.77
	489	0.09	13.5	1.38	15.00	13.62	51.04	49.83	55.88	49.34
	496	0.0925	13.875	1.41	15.00	13.59	51.63	50.40	56.52	49.91
Peak Flow Rate	503	0.095	14.25	1.45	15.00	13.55	52.21	50.97	57.16	50.47
	510	0.0975	14.625	1.49	15.00	13.51	52.79	51.53	57.79	51.03

Table 13: Power Output from 150m Length of 450mm Diameter Pipe at a 15m Head

	Mass Flow Rate (kg/s)	Delta P Pipe (kPa/m)	Delta P (kPa)	Delta P (m)	Head (m)	Effective head (m)	44% Flow Power at 78.1% system Efficiency (kW)	34% Flow Power at 76.24% system Efficiency (kW)	100%flow Power at 85.5% system Efficiency (kW)	30% Flow Power at 75.5% system Efficiency (kW)
Nov & Feb STOD	165	0.02	3	0.31	15.00	14.69	18.58	18.13	20.34	17.96
Jan & Dec weekends	176	0.0225	3.375	0.34	15.00	14.66	19.76	19.29	21.64	19.10
	186	0.025	3.75	0.38	15.00	14.62	20.83	20.34	22.80	20.14
	196	0.0275	4.125	0.42	15.00	14.58	21.89	21.37	23.97	21.16
	205	0.03	4.5	0.46	15.00	14.54	22.84	22.30	25.00	22.08
	214	0.0325	4.875	0.50	15.00	14.50	23.78	23.21	26.03	22.99
Sustainable Flow Rate	223	0.035	5.25	0.54	15.00	14.46	24.71	24.13	27.06	23.89
	231	0.0375	5.625	0.57	15.00	14.43	25.53	24.92	27.95	24.68
	239	0.04	6	0.61	15.00	14.39	26.35	25.72	28.84	25.47
	247	0.0425	6.375	0.65	15.00	14.35	27.16	26.51	29.73	26.25
	255	0.045	6.75	0.69	15.00	14.31	27.96	27.30	30.61	27.03
	262	0.0475	7.125	0.73	15.00	14.27	28.65	27.97	31.37	27.70
	269	0.05	7.5	0.76	15.00	14.24	29.34	28.64	32.12	28.36
	276	0.0525	7.875	0.80	15.00	14.20	30.02	29.31	32.87	29.02
	283	0.055	8.25	0.84	15.00	14.16	30.70	29.97	33.61	29.68
	290	0.0575	8.625	0.88	15.00	14.12	31.37	30.63	34.35	30.33
	296	0.06	9	0.92	15.00	14.08	31.94	31.18	34.96	30.87
	303	0.0625	9.375	0.96	15.00	14.04	32.60	31.83	35.69	31.52
	309	0.065	9.75	0.99	15.00	14.01	33.16	32.37	36.30	32.05
	315	0.0675	10.125	1.03	15.00	13.97	33.71	32.91	36.90	32.59
	321	0.07	10.5	1.07	15.00	13.93	34.26	33.44	37.50	33.12
	327	0.0725	10.875	1.11	15.00	13.89	34.80	33.97	38.10	33.64
	333	0.075	11.25	1.15	15.00	13.85	35.34	34.50	38.69	34.17
	339	0.0775	11.625	1.19	15.00	13.81	35.88	35.03	39.28	34.69
	345	0.08	12	1.22	15.00	13.78	36.42	35.55	39.87	35.20

	350	0.0825	12.375	1.26	15.00	13.74	36.84	35.96	40.33	35.61
	356	0.085	12.75	1.30	15.00	13.70	37.37	36.48	40.91	36.12
	361	0.0875	13.125	1.34	15.00	13.66	37.79	36.89	41.37	36.53
	367	0.09	13.5	1.38	15.00	13.62	38.31	37.40	41.94	37.03
	372	0.0925	13.875	1.41	15.00	13.59	38.72	37.80	42.39	37.43
	377	0.095	14.25	1.45	15.00	13.55	39.13	38.20	42.84	37.83
	383	0.0975	14.625	1.49	15.00	13.51	39.64	38.70	43.40	38.32
	388	0.1	15	1.53	15.00	13.47	40.05	39.09	43.84	38.71
	427	0.12	18	1.83	15.00	13.17	43.07	42.04	47.15	41.64
	462	0.14	21	2.14	15.00	12.86	45.52	44.43	49.83	44.00
Peak Flow Rate	496	0.16	24	2.45	15.00	12.55	47.71	46.57	52.23	46.12
	527	0.18	27	2.75	15.00	12.25	49.45	48.27	54.14	47.81
	557	0.2	30	3.06	15.00	11.94	50.96	49.75	55.79	49.27

Table 14: Power Output from 150m Length of 400mm Diameter Pipe at a 15m Head

	Mass Flow Rate (kg/s)	Delta P Pipe (kPa/m)	Delta P (kPa)	Delta P (m)	Head (m)	Effective Head (m)	44% Flow Power at 78.1% system Efficiency (kW)	34% Flow Power at 76.24% system Efficiency (kW)	100%flow Power at 85.5% system Efficiency (kW)	30% Flow Power at 75.5% system Efficiency (kW)
Nov & Feb STOD	164	0.03	4.5	0.459	15	14.54	18.27	17.84	20.00	17.66
	164	0.0325	4.875	0.497	15	14.50	18.22	17.79	19.95	17.62
	164	0.035	5.25	0.535	15	14.46	18.18	17.74	19.90	17.57
	170	0.0375	5.625	0.573	15	14.43	18.79	18.34	20.57	18.16
Jan & Dec weekends	176	0.04	6	0.612	15	14.39	19.40	18.94	21.24	18.76
	181	0.0425	6.375	0.650	15	14.35	19.90	19.43	21.79	19.24
	187	0.045	6.75	0.688	15	14.31	20.50	20.02	22.45	19.82
	192	0.0475	7.125	0.726	15	14.27	21.00	20.50	22.99	20.30
	198	0.05	7.5	0.765	15	14.24	21.60	21.08	23.64	20.88
	203	0.0525	7.875	0.803	15	14.20	22.08	21.56	24.17	21.35
	208	0.055	8.25	0.841	15	14.16	22.56	22.03	24.70	21.81
	213	0.0575	8.625	0.879	15	14.12	23.04	22.50	25.23	22.28
	218	0.06	9	0.917	15	14.08	23.52	22.96	25.75	22.74
Sustainable Flow Rate	222	0.0625	9.375	0.956	15	14.04	23.89	23.32	26.15	23.09
	227	0.065	9.75	0.994	15	14.01	24.36	23.78	26.67	23.55
	232	0.0675	10.125	1.032	15	13.97	24.83	24.24	27.18	24.00
	236	0.07	10.5	1.070	15	13.93	25.19	24.59	27.57	24.35
	241	0.0725	10.875	1.109	15	13.89	25.65	25.04	28.08	24.80
	245	0.075	11.25	1.147	15	13.85	26.00	25.38	28.47	25.14
	249	0.0775	11.625	1.185	15	13.81	26.36	25.73	28.85	25.48
	253	0.08	12	1.223	15	13.78	26.70	26.07	29.23	25.82
	258	0.0825	12.375	1.261	15	13.74	27.16	26.51	29.73	26.25
	262	0.085	12.75	1.300	15	13.70	27.50	26.85	30.11	26.59
	266	0.0875	13.125	1.338	15	13.66	27.84	27.18	30.48	26.92
	270	0.09	13.5	1.376	15	13.62	28.18	27.51	30.85	27.24
	273	0.0925	13.875	1.414	15	13.59	28.42	27.74	31.11	27.47

	277	0.095	14.25	1.453	15	13.55	28.75	28.07	31.48	27.79
	281	0.0975	14.625	1.491	15	13.51	29.08	28.39	31.84	28.12
	285	0.1	15	1.529	15	13.47	29.41	28.71	32.20	28.44
	313	0.12	18	1.835	15	13.17	31.57	30.82	34.56	30.52
	340	0.14	21	2.141	15	12.86	33.50	32.70	36.67	32.38
	364	0.16	24	2.446	15	12.55	35.01	34.18	38.33	33.84
	387	0.18	27	2.752	15	12.25	36.31	35.45	39.76	35.11
	409	0.2	30	3.058	15	11.94	37.42	36.53	40.97	36.18
	430	0.22	33	3.364	15	11.64	38.33	37.42	41.97	37.06
	450	0.24	36	3.670	15	11.33	39.06	38.13	42.76	37.76
	469	0.26	39	3.976	15	11.02	39.61	38.67	43.37	38.30
	487	0.28	42	4.281	15	10.72	39.99	39.04	43.78	38.66
Peak Flow Rate	505	0.3	45	4.587	15	10.41	40.29	39.33	44.11	38.95
	522	0.32	48	4.893	15	10.11	40.42	39.46	44.25	39.08
	539	0.34	51	5.199	15	9.80	40.48	39.51	44.31	39.13
	555	0.36	54	5.505	15	9.50	40.38	39.41	44.20	39.03
	571	0.38	57	5.810	15	9.19	40.20	39.25	44.01	38.86
	586	0.4	60	6.116	15	8.88	39.89	38.94	43.66	38.56

Table 15: Power Output from 260m Length of 500mm Diameter Pipe at a 17m Head

	Mass Flow Rate (kg/s)	Delta P Pipe (kPa/m)	Delta P (kPa)	Delta P (m)	Head (m)	Effective Head (m)	44% Flow Power at 78.1% System Efficiency(kW)	34% Flow Power at 76.24% System Efficiency (kW)	100%flow Power at 85.5% System Efficiency (kW)	30% Flow Power at 75.5% System Efficiency (kW)
	144	0.009	2.34	0.24	17.00	16.76	18.49	18.05	20.24	17.88
	148	0.0095	2.47	0.25	17.00	16.75	18.99	18.54	20.79	18.36
Nov & Feb STOD	152	0.01	2.6	0.27	17.00	16.73	19.49	19.02	21.34	18.84
Jan & Dec weekends	172	0.0125	3.25	0.33	17.00	16.67	21.97	21.44	24.05	21.23
	189	0.015	3.9	0.40	17.00	16.60	24.04	23.47	26.32	23.24
	205	0.0175	4.55	0.46	17.00	16.54	25.97	25.35	28.43	25.11
Sustainable Flow Rate	221	0.02	5.2	0.53	17.00	16.47	27.89	27.22	30.53	26.96
	235	0.0225	5.85	0.60	17.00	16.40	29.53	28.83	32.33	28.55
	249	0.025	6.5	0.66	17.00	16.34	31.17	30.43	34.12	30.13
	262	0.0275	7.15	0.73	17.00	16.27	32.66	31.88	35.76	31.57
	274	0.03	7.8	0.80	17.00	16.20	34.02	33.21	37.24	32.89
	286	0.0325	8.45	0.86	17.00	16.14	35.36	34.52	38.71	34.19
	297	0.035	9.1	0.93	17.00	16.07	36.57	35.70	40.04	35.36
	308	0.0375	9.75	0.99	17.00	16.01	37.77	36.87	41.35	36.51
	319	0.04	10.4	1.06	17.00	15.94	38.96	38.03	42.65	37.66
	329	0.0425	11.05	1.13	17.00	15.87	40.01	39.06	43.80	38.68
	340	0.045	11.7	1.19	17.00	15.81	41.18	40.20	45.08	39.81
	349	0.0475	12.35	1.26	17.00	15.74	42.09	41.09	46.08	40.69
	359	0.05	13	1.33	17.00	15.67	43.11	42.09	47.20	41.68
	368	0.0525	13.65	1.39	17.00	15.61	44.01	42.96	48.18	42.54
	378	0.055	14.3	1.46	17.00	15.54	45.01	43.94	49.28	43.51
	386	0.0575	14.95	1.52	17.00	15.48	45.77	44.68	50.11	44.24
	395	0.06	15.6	1.59	17.00	15.41	46.64	45.52	51.05	45.08
	404	0.0625	16.25	1.66	17.00	15.34	47.49	46.36	51.99	45.91

	412	0.065	16.9	1.72	17.00	15.28	48.22	47.08	52.79	46.62
	420	0.0675	17.55	1.79	17.00	15.21	48.95	47.78	53.58	47.32
	429	0.07	18.2	1.86	17.00	15.14	49.78	48.59	54.49	48.12
	437	0.0725	18.85	1.92	17.00	15.08	50.48	49.28	55.27	48.80
	444	0.075	19.5	1.99	17.00	15.01	51.07	49.85	55.91	49.37
	452	0.0775	20.15	2.05	17.00	14.95	51.76	50.53	56.66	50.04
	460	0.08	20.8	2.12	17.00	14.88	52.44	51.19	57.41	50.70
	467	0.0825	21.45	2.19	17.00	14.81	53.00	51.74	58.02	51.24
	475	0.085	22.1	2.25	17.00	14.75	53.67	52.39	58.75	51.88
	482	0.0875	22.75	2.32	17.00	14.68	54.22	52.92	59.35	52.41
	489	0.09	23.4	2.39	17.00	14.61	54.75	53.45	59.94	52.93
	496	0.0925	24.05	2.45	17.00	14.55	55.29	53.97	60.52	53.45
Peak Flow Rate	503	0.095	24.7	2.52	17.00	14.48	55.81	54.48	61.10	53.95
	510	0.0975	25.35	2.58	17.00	14.42	56.33	54.99	61.67	54.45

Table 16: Power Output from 260m Length of 450mm Diameter Pipe at a 15m Head

	Mass Flow Rate (kg/s)	Delta P Pipe (kPa/m)	Delta P (kPa)	Delta P (m)	Head (m)	Effective head (m)	44% Flow Power at 78.1% System Efficiency (kW)	34% Flow Power at 76.24% System Efficiency (kW)	100%flow Power at 85.5% System Efficiency (kW)	30% Flow Power at 75.5% System Efficiency (kW)
Nov & Feb STOD	165	0.02	5.2	0.53	17.00	16.47	20.82	20.32	22.79	20.13
Jan & Dec weekends	176	0.0225	5.85	0.60	17.00	16.40	22.12	21.59	24.22	21.38
	186	0.025	6.5	0.66	17.00	16.34	23.28	22.73	25.49	22.51
	196	0.0275	7.15	0.73	17.00	16.27	24.43	23.85	26.75	23.62
	205	0.03	7.8	0.80	17.00	16.20	25.45	24.85	27.86	24.60
Sustainable Flow Rate	214	0.0325	8.45	0.86	17.00	16.14	26.46	25.83	28.97	25.58
	223	0.035	9.1	0.93	17.00	16.07	27.46	26.81	30.06	26.55
	231	0.0375	9.75	0.99	17.00	16.01	28.33	27.65	31.01	27.39
	239	0.04	10.4	1.06	17.00	15.94	29.19	28.49	31.95	28.22
	247	0.0425	11.05	1.13	17.00	15.87	30.04	29.32	32.89	29.04
	255	0.045	11.7	1.19	17.00	15.81	30.88	30.15	33.81	29.85
	262	0.0475	12.35	1.26	17.00	15.74	31.60	30.85	34.59	30.55
	269	0.05	13	1.33	17.00	15.67	32.31	31.54	35.37	31.23
	276	0.0525	13.65	1.39	17.00	15.61	33.01	32.22	36.13	31.91
	283	0.055	14.3	1.46	17.00	15.54	33.70	32.90	36.89	32.58
	290	0.0575	14.95	1.52	17.00	15.48	34.39	33.57	37.64	33.24
	296	0.06	15.6	1.59	17.00	15.41	34.95	34.11	38.26	33.78
	303	0.0625	16.25	1.66	17.00	15.34	35.62	34.77	38.99	34.43
	309	0.065	16.9	1.72	17.00	15.28	36.17	35.31	39.59	34.96
	315	0.0675	17.55	1.79	17.00	15.21	36.71	35.84	40.19	35.49
	321	0.07	18.2	1.86	17.00	15.14	37.25	36.36	40.78	36.01
	327	0.0725	18.85	1.92	17.00	15.08	37.78	36.88	41.36	36.52
	333	0.075	19.5	1.99	17.00	15.01	38.30	37.39	41.93	37.03
	339	0.0775	20.15	2.05	17.00	14.95	38.82	37.89	42.50	37.53
	345	0.08	20.8	2.12	17.00	14.88	39.33	38.39	43.06	38.02

	350	0.0825	21.45	2.19	17.00	14.81	39.72	38.78	43.49	38.40
	356	0.085	22.1	2.25	17.00	14.75	40.22	39.27	44.03	38.88
	361	0.0875	22.75	2.32	17.00	14.68	40.61	39.64	44.45	39.25
	367	0.09	23.4	2.39	17.00	14.61	41.09	40.12	44.99	39.73
	372	0.0925	24.05	2.45	17.00	14.55	41.46	40.48	45.39	40.08
	377	0.095	24.7	2.52	17.00	14.48	41.83	40.83	45.79	40.44
	383	0.0975	25.35	2.58	17.00	14.42	42.30	41.29	46.31	40.89
	388	0.1	26	2.65	17.00	14.35	42.66	41.64	46.70	41.24
	427	0.12	31.2	3.18	17.00	13.82	45.21	44.13	49.49	43.71
	462	0.14	36.4	3.71	17.00	13.29	47.04	45.92	51.50	45.47
Peak Flow Rate	496	0.16	41.6	4.24	17.00	12.76	48.49	47.33	53.08	46.87
	527	0.18	46.8	4.77	17.00	12.23	49.38	48.20	54.06	47.73
	557	0.2	52	5.30	17.00	11.70	49.93	48.74	54.66	48.26

Table 17: Power Output from 260m Length of 400mm Diameter Pipe at a 17m Head

	Mass Flow Rate (kg/s)	Delta P Pipe (kPa/m)	Delta P (kPa)	Delta P (m)	Head (m)	Effective head (m)	44% Flow Power at 78.1% system Efficiency (kW)	34% Flow Power at 76.24% system Efficiency (kW)	100%flow Power at 85.5% system Efficiency (kW)	30% Flow Power at 75.5% system Efficiency (kW)
Nov & Feb STOD	164	0.03	7.8	0.795	17	16.20	20.36	19.88	22.29	19.68
	164	0.0325	8.45	0.861	17	16.14	20.28	19.80	22.20	19.60
	164	0.035	9.1	0.928	17	16.07	20.20	19.71	22.11	19.52
	170	0.0375	9.75	0.994	17	16.01	20.85	20.35	22.82	20.15
Jan & Dec weekends	176	0.04	10.4	1.060	17	15.94	21.49	20.98	23.53	20.78
	181	0.0425	11.05	1.126	17	15.87	22.01	21.49	24.10	21.28
	187	0.045	11.7	1.193	17	15.81	22.65	22.11	24.79	21.89
	192	0.0475	12.35	1.259	17	15.74	23.16	22.60	25.35	22.38
	198	0.05	13	1.325	17	15.67	23.78	23.21	26.03	22.99
	203	0.0525	13.65	1.391	17	15.61	24.28	23.70	26.58	23.47
	208	0.055	14.3	1.458	17	15.54	24.77	24.18	27.12	23.94
	213	0.0575	14.95	1.524	17	15.48	25.26	24.65	27.65	24.41
	218	0.06	15.6	1.590	17	15.41	25.74	25.12	28.18	24.88
Sustainable Flow Rate	222	0.0625	16.25	1.656	17	15.34	26.10	25.48	28.57	25.23
	227	0.065	16.9	1.723	17	15.28	26.57	25.94	29.09	25.69
	232	0.0675	17.55	1.789	17	15.21	27.04	26.39	29.60	26.14
	236	0.07	18.2	1.855	17	15.14	27.38	26.73	29.98	26.47
	241	0.0725	18.85	1.922	17	15.08	27.84	27.18	30.48	26.91
	245	0.075	19.5	1.988	17	15.01	28.18	27.51	30.85	27.24
	249	0.0775	20.15	2.054	17	14.95	28.51	27.83	31.21	27.56
	253	0.08	20.8	2.120	17	14.88	28.84	28.16	31.58	27.88
	258	0.0825	21.45	2.187	17	14.81	29.28	28.58	32.06	28.31
	262	0.085	22.1	2.253	17	14.75	29.60	28.90	32.41	28.62
	266	0.0875	22.75	2.319	17	14.68	29.92	29.21	32.75	28.92
	270	0.09	23.4	2.385	17	14.61	30.23	29.51	33.10	29.23
	273	0.0925	24.05	2.452	17	14.55	30.43	29.71	33.31	29.42

	277	0.095	24.7	2.518	17	14.48	30.73	30.00	33.65	29.71
	281	0.0975	25.35	2.584	17	14.42	31.04	30.30	33.98	30.00
	285	0.1	26	2.650	17	14.35	31.33	30.59	34.30	30.29
	313	0.12	31.2	3.180	17	13.82	33.14	32.35	36.28	32.04
	340	0.14	36.4	3.710	17	13.29	34.62	33.79	37.90	33.47
	364	0.16	41.6	4.241	17	12.76	35.58	34.74	38.96	34.40
	387	0.18	46.8	4.771	17	12.23	36.26	35.40	39.70	35.05
	409	0.2	52	5.301	17	11.70	36.66	35.79	40.13	35.44
	430	0.22	57.2	5.831	17	11.17	36.80	35.92	40.28	35.57
	450	0.24	62.4	6.361	17	10.64	36.68	35.81	40.16	35.46
	469	0.26	67.6	6.891	17	10.11	36.32	35.46	39.77	35.12
	487	0.28	72.8	7.421	17	9.58	35.74	34.89	39.13	34.55
Peak Flow Rate	505	0.3	78	7.951	17	9.05	35.01	34.18	38.33	33.85
	522	0.32	83.2	8.481	17	8.52	34.07	33.26	37.30	32.94
	539	0.34	88.4	9.011	17	7.99	32.99	32.20	36.12	31.89
	555	0.36	93.6	9.541	17	7.46	31.72	30.96	34.72	30.66
	571	0.38	98.8	10.071	17	6.93	30.31	29.59	33.18	29.30
	586	0.4	104	10.601	17	6.40	28.73	28.04	31.45	27.77

Appendix E – Potential Revenue from Different NIE Tariffs

Table 18: Potential Revenue from Exploris with the Generator sited at the 15m Head

	Number of Daily Hours	Number of Days	Number of Hours/Year	Exploris Tariff (p/kWh)	NIE Wheeling Charge (p/kWh)	Unit Income for SWL & CA (p/kWh)	Power Output 400mm Diameter Pipe (kW) 15m head	Annual Energy (kWh)	Revenue (£)
March & October 0800-2030 hours (weekdays)	12.5	44	550	6.4	0.476	5.924	23.89	13,140	£778
March & October 2030-2230 hours (weekday Evenings)	2	44	88	3.5	0.545	2.955	23.89	2,102	£62
March & October 2230-0800 hours (weekday Nights)	9.5	44	418	3.5	0.226	3.274	23.89	9,986	£327
March & October (weekends)	24	18	432	3.5	0.545	2.955	23.89	10,320	£305
Nov + Feb (weekday Outside SToD hours)	21	42	882	9.6	1.379	8.221	18.94	16,705	£1,373
Jan + Dec (weekday)	21	45	945	9.6	2.76	6.84	18.94	17,898	£1,224
Nov + Feb (SToD 1600-1900 hours)	3	42	126	48	11.872	36.128	44.11	5,558	£2,008
Jan + Dec (SToD 1600-1900 hours)	3	45	135	48	12.671	35.329	44.11	5,955	£2,104
Nov - Feb (weekends)	24	33	792	3.5	0.545	2.955	23.89	18,921	£559
April - September between 0800-2030 hours weekdays	6.7	131	877.7	6.4	0.476	5.924	17.66	15,500	£918
TOTAL								**116,085**	**£9,659**
	Number of Daily Hours	Number of Days	Number of Hours/Year	Exploris Tariff (p/kWh)	NIE Wheeling Charge (p/kWh)	Unit Income for SWL & CA (p/kWh)	Power Output 450mm Diameter Pipe (kWh)15m head	Annual Energy (kWh)	Revenue (£)
March & October 0800-2030 hours (weekdays)	12.5	44	550	6.4	0.476	5.924	24.71	13,591	£805
March & October 2030-2230 hours (weekday Evenings)	2	44	88	3.5	0.545	2.955	24.71	2,174	£64
March & October 2230-0800 hours (weekday Nights)	9.5	44	418	3.5	0.226	3.274	24.71	10,329	£338
March & October (weekends)	24	18	432	3.5	0.545	2.955	24.71	10,675	£315
Nov + Feb (weekday Outside SToD	21	42	882	9.6	1.379	8.221	19.29	17,014	£1,399

hours)									
Jan + Dec (weekday)	21	45	945	9.6	2.76	6.84	19.29	18,229	£1,247
Nov + Feb (SToD 1600-1900 hours)	3	42	126	48	11.872	36.128	46.57	5,868	£2,120
Jan + Dec (SToD 1600-1900 hours)	3	45	135	48	12.671	35.329	46.57	6,287	£2,221
Nov - Feb (weekends)	24	33	792	3.5	0.545	2.955	24.71	19,570	£578
April - September between 0800-2030 hours weekdays	6.7	131	877.7	6.4	0.476	5.924	17.96	15,763	£934
TOTAL								**119,500**	**£10,022**

	Number of Daily Hours	Number of Days	Number of Hours/Year	Exploris Tariff (p/kWh)	NIE Wheeling Charge (p/kWh)	Unit Income for SWL & CA (p/kWh)	Power Output 500mm Diameter Pipe (kWh)15m head	Annual Energy (kWh)	Revenue (£)
March & October 0800-2030 hours (weekdays)	12.5	44	550	6.4	0.476	5.924	24.88	13,684	£811
March & October 2030-2230 hours (weekday Evenings)	2	44	88	3.5	0.545	2.955	24.88	2,189	£65
March & October 2230-0800 hours (weekday Nights)	9.5	44	418	3.5	0.226	3.274	24.88	10,400	£340
March & October (weekends)	24	18	432	3.5	0.545	2.955	24.88	10,748	£318
Nov + Feb (weekday Outside SToD hours)	21	42	882	9.6	1.379	8.221	18.81	16,590	£1,364
Jan + Dec (weekday)	21	45	945	9.6	2.76	6.84	18.81	17,775	£1,216
Nov + Feb (SToD 1600-1900 hours)	3	42	126	48	11.872	36.128	57.16	7,202	£2,602
Jan + Dec (SToD 1600-1900 hours)	3	45	135	48	12.671	35.329	57.16	7,717	£2,726
Nov - Feb (weekends)	24	33	792	3.5	0.545	2.955	24.88	19,705	£582
April - September between 0800-2030 hours weekdays	6.7	131	877.7	6.4	0.476	5.924	16.71	14,666	£869
TOTAL								**120,677**	**£10,892**

Table 19: Potential Revenue from Business Multi Rate Option (Under 1MW High Voltage) the Generator sited at the 15m Head

	Number of Daily Hours	Number of Days	Number of Hours/Year	Business Tariff (p/kWh)	NIE Wheeling Charge (p/kWh)	Unit Income for SWL & CA (p/kWh)	Power Output 400mm Diameter Pipe (kWh)15m head	Annual Energy (kWh)	Revenue (£)
March & October 0800-2030 hours (weekdays)	12.5	44	550	6	0.257	5.743	23.89	13,140	£755
March & October 2030-2230 hours (weekday Evenings)	2	44	88	3.7	0.308	3.392	23.89	2,102	£71
March & October 2230-0800 hours (weekday Nights)	9.5	44	418	3.7	0.155	3.545	23.89	9,986	£354
March & October (weekends)	24	18	432	3.7	0.308	3.392	23.89	10,320	£350
Nov + Feb (weekday Outside SToD hours)	21	42	882	8.7	0.888	7.812	18.94	16,705	£1,305
Jan + Dec (weekday)	21	45	945	8.7	1.95	6.75	18.94	17,898	£1,208
Nov + Feb (SToD 1600-1900 hours)	3	42	126	45	5.205	39.795	44.11	5,558	£2,212
Jan + Dec (SToD 1600-1900 hours)	3	45	135	45	5.611	39.389	44.11	5,955	£2,346
Nov - Feb (weekends)	24	33	792	3.7	0.308	3.392	23.89	18,921	£642
April - September between 0800-2030 hours weekdays	6.7	131	877.7	6	0.257	5.743	17.66	15,500	£890
TOTAL								116,085	£10,132

	Number of Daily Hours	Number of Days	Number of Hours/Year	Business Tariff (p/kWh)	NIE Wheeling Charge (p/kWh)	Unit Income for SWL & CA (p/kWh)	Power Output 450mm Diameter Pipe (kWh)15m head	Annual Energy (kWh)	Revenue (£)
March & October 0800-2030 hours (weekdays)	12.5	44	550	6	0.257	5.743	24.71	13,591	£781
March & October 2030-2230 hours (weekday Evenings)	2	44	88	3.7	0.308	3.392	24.71	2,174	£74
March & October 2230-0800 hours (weekday Nights)	9.5	44	418	3.7	0.155	3.545	24.71	10,329	£366
March & October (weekends)	24	18	432	3.7	0.308	3.392	24.71	10,675	£362
Nov + Feb (weekday Outside SToD hours)	21	42	882	8.7	0.888	7.812	19.29	17,014	£1,329

Jan + Dec (weekday)	21	45	945	8.7	1.95	6.75	19.29	18,229	£1,230
Nov + Feb (SToD 1600-1900 hours)	3	42	126	45	5.205	39.795	46.57	5,868	£2,335
Jan + Dec (SToD 1600-1900 hours)	3	45	135	45	5.611	39.389	46.57	6,287	£2,476
Nov - Feb (weekends)	24	33	792	3.7	0.308	3.392	24.71	19,570	£664
April - September between 0800-2030 hours weekdays	6.7	131	877.7	6	0.257	5.743	17.96	15,763	£905
TOTAL								**119,500**	**£10,523**

	Number of Daily Hours	Number of Days	Number of Hours/Year	Business Tariff (p/kWh)	NIE Wheeling Charge (p/kWh)	Unit Income for SWL & CA (p/kWh)	Power Output 500mm Diameter Pipe (kWh)15m head	Annual Energy (kWh)	Revenue (£)
March & October 0800-2030 hours (weekdays)	12.5	44	550	6	0.257	5.743	24.88	13,684	£786
March & October 2030-2230 hours (weekday Evenings)	2	44	88	3.7	0.308	3.392	24.88	2,189	£74
March & October 2230-0800 hours (weekday Nights)	9.5	44	418	3.7	0.155	3.545	24.88	10,400	£369
March & October (weekends)	24	18	432	3.7	0.308	3.392	24.88	10,748	£365
Nov + Feb (weekday Outside SToD hours)	21	42	882	8.7	0.888	7.812	18.81	16,590	£1,296
Jan + Dec (weekday)	21	45	945	8.7	1.95	6.75	18.81	17,775	£1,200
Nov + Feb (SToD 1600-1900 hours)	3	42	126	45	5.205	39.795	57.16	7,202	£2,866
Jan + Dec (SToD 1600-1900 hours)	3	45	135	45	5.611	39.389	57.16	7,717	£3,039
Nov - Feb (weekends)	24	33	792	3.7	0.308	3.392	24.88	19,705	£668
April - September between 0800-2030 hours weekdays	6.7	131	877.7	6	0.257	5.743	16.71	14,666	£842
TOTAL								**120,677**	**£11,506**

Table 20: Potential Revenue from Farm Energy Tariff (Under 1MW High Voltage) with the Generator sited at the 15m Head

	Number of Daily Hours	Number of Days	Number of Hours/Year	Business Tariff (p/kWh)	NIE Wheeling Charge (p/kWh)	Unit Income for SWL & CA (p/kWh)	Power Output 400mm Diameter Pipe (kWh)15m head	Annual Energy (kWh)	Revenue (£)
March & October 0800-2030 hours (weekdays)	12.5	44	550	5.9	0.257	5.643	23.89	13,140	£741
March & October 2030-2230 hours (weekday Evenings)	2	44	88	3.3	0.308	2.992	23.89	2,102	£63
March & October 2230-0800 hours (weekday Nights)	9.5	44	418	3.3	0.155	3.145	23.89	9,986	£314
March & October (weekends)	24	18	432	3.3	0.308	2.992	23.89	10,320	£309
Nov + Feb (weekday Outside SToD hours)	21	42	882	8.6	0.888	7.712	18.94	16,705	£1,288
Jan + Dec (weekday)	21	45	945	8.6	1.95	6.65	18.94	17,898	£1,190
Nov + Feb (SToD 1600-1900 hours)	3	42	126	43	5.205	37.795	44.11	5,558	£2,101
Jan + Dec (SToD 1600-1900 hours)	3	45	135	43	5.611	37.389	44.11	5,955	£2,226
Nov - Feb (weekends)	24	33	792	3.3	0.308	2.992	23.89	18,921	£566
April - September between 0800-2030 hours weekdays	6.7	131	877.7	5.9	0.257	5.643	17.66	15,500	£875
TOTAL								**116,085**	**£9,674**
	Number of Daily Hours	Number of Days	Number of Hours/Year	Business Tariff (p/kWh)	NIE Wheeling Charge (p/kWh)	Unit Income for SWL & CA (p/kWh)	Power Output 450mm Diameter Pipe (kWh)15m head	Annual Energy (kWh)	Revenue (£)
March & October 0800-2030 hours (weekdays)	12.5	44	550	5.9	0.257	5.643	24.71	13,591	£767
March & October 2030-2230 hours (weekday Evenings)	2	44	88	3.3	0.308	2.992	24.71	2,174	£65
March & October 2230-0800 hours (weekday Nights)	9.5	44	418	3.3	0.155	3.145	24.71	10,329	£325
March & October (weekends)	24	18	432	3.3	0.308	2.992	24.71	10,675	£319
Nov + Feb (weekday Outside SToD hours)	21	42	882	8.6	0.888	7.712	19.29	17,014	£1,312
Jan + Dec (weekday)	21	45	945	8.6	1.95	6.65	19.29	18,229	£1,212
Nov + Feb (SToD 1600-1900 hours)	3	42	126	43	5.205	37.795	46.57	5,868	£2,218

Jan + Dec (SToD 1600-1900 hours)	3	45	135	43	5.611	37.389	46.57	6,287	£2,351
Nov - Feb (weekends)	24	33	792	3.3	0.308	2.992	24.71	19,570	£586
April - September between 0800-2030 hours weekdays	6.7	131	877.7	5.9	0.257	5.643	17.96	15,763	£890
TOTAL								**119,500**	**£10,044**

	Number of Daily Hours	Number of Days	Number of Hours/Year	Business Tariff (p/kWh)	NIE Wheeling Charge (p/kWh)	Unit Income for SWL & CA (p/kWh)	Power Output 500mm Diameter Pipe (kWh)15m head	Annual Energy (kWh)	Revenue (£)
March & October 0800-2030 hours (weekdays)	12.5	44	550	5.9	0.257	5.643	24.88	13,684	£772
March & October 2030-2230 hours (weekday Evenings)	2	44	88	3.3	0.308	2.992	24.88	2,189	£66
March & October 2230-0800 hours (weekday Nights)	9.5	44	418	3.3	0.155	3.145	24.88	10,400	£327
March & October (weekends)	24	18	432	3.3	0.308	2.992	24.88	10,748	£322
Nov + Feb (weekday Outside SToD hours)	21	42	882	8.6	0.888	7.712	18.81	16,590	£1,279
Jan + Dec (weekday)	21	45	945	8.6	1.95	6.65	18.81	17,775	£1,182
Nov + Feb (SToD 1600-1900 hours)	3	42	126	43	5.205	37.795	57.16	7,202	£2,722
Jan + Dec (SToD 1600-1900 hours)	3	45	135	43	5.611	37.389	57.16	7,717	£2,885
Nov - Feb (weekends)	24	33	792	3.3	0.308	2.992	24.88	19,705	£590
April - September between 0800-2030 hours weekdays	6.7	131	877.7	5.9	0.257	5.643	16.71	14,666	£828
TOTAL								**120,677**	**£10,972**

Appendix F – Letters of Support for the Micro-hydro Project

26 Feb 04 13:31 Robert Morrison 028 9071 9977 p.7

DUNDONALD PRIMARY SCHOOL

9/2/04

Dear Mr Brown,

Thank you for your letter. I wish to inform you that Dundonald Primary would be interested in organising an educational visit for the primary five classes. In the interim, I would be grateful if you could forward your list of possible educational activities for us to mull over.

Yours sincerely,

Gillian Neill

Principal: Mrs. R. J. E. Brittain Cert. Ed. M.Sc.
10 Church Green, Dundonald, Belfast. BT16 2LP Tel: (028) 9048 2680 Fax: (028) 9041 0931
Email: Principal:rbrittain@ddps.belfast.ni.sch.uk or office:agraham@ddps.belfast.ni.sch.uk

26 Feb 04 13:32 Robert Morrison 028 9071 9977 p.11

Established 1888

Kirkistown Primary School

Main Road,
CLOUGHEY,
Newtownards,
Co. Down, BT22 1JA.

Tel. No. (028) 427 71455
PRINCIPAL: Mrs JM Wallace, MEd BA(Hons)

11th February 2004

Dear Mr Brown

In response to your letter of last week, I would confirm that our school would most certainly be interested in using possible educational facilities. As a school we are committed to supporting conservation through many avenues, but realise that often we do not appreciate nature on our doorstep.

Unfortunately, due to prior engagement, I am unable to view the facilities on 20th February, but would appreciate being kept informed of progress and assure you of our support.

Yours sincerely

Jillian Wallace

Mrs J Wallace
Principal

eb 04 13:31 Robert Morrison 028 9071 9977

SOUTH EASTERN EDUCATION AND LIBRARY BOARD
KILLARD HOUSE SCHOOL

PRINCIPAL: **W Haddick MA**

Telephone: **(01247) 813613,**
Fax: **(01247) 822073**

North Road
NEWTOWNARDS
Co. Down
BT23 7AP

Schools Curriculum

Award

13 February 2004

Mr F Brown
General Secretary
Strangford Lough Wildfowlers
& Conservation Association
Glenvale Hall
45 Crawfordsburn Road
NEWTOWNARDS
Co Down
BT23 4EA

Dear Mr Brown

Thank you for the information on your Conservation Area in Newtownards. Access to such a facility would be of great interest to us.

Killard House is a special school providing for 195 children ranging in age from 4yrs to 16yrs. 150 of the children are assessed as having moderate learning difficulties while 45 have speech & language difficulties.

Killard House has permanent Eco-schools status so environmental and conservation issues are important in school. We have a policy of ensuring that the children can gain first hand experiences to enhance learning. To this end we undertake an extensive range of educational visits. Obviously your facility, being so close to school, would offer us a great opportunity to enhance the environmental aspects of the curriculum.

Some of the activities that would interest us would

Nature walks (for infants)
Wildlife observation - plants, animals, insects etc
Project work.

Our school will be fitted out with a computer intranet next month which will mean each classroom will have an internet connection. The suggestion that webcams could be used to bring the Conservation Area is an exciting one and we can see a wide range of uses. Eg from learning about the seasons to monitoring a particular aspect of life in the area as part of a science project.

We are delighted to lend your support to the project outlined in your letter and hopefully look forward to the opportunity to work with you in the future.

Kindest regards

Yours sincerely

W.J Haddick .

WJ Haddick
Principal

LONDONDERRY PRIMARY SCHOOL

Principal: Mr A.J. Moore

6 February 2004

Dear Mr Brown,

I thank you for your letter regarding the future proposals for the site. My school would be extremely interested in its development as an educational resource - particularly as we are the closest school.

I see the development as being particularly useful as a 'hands on' for the study of science and conservation - all age groups would be able to use it in all seasons and be able to 'tie in' to the curriculum for each year.

Happy to support the initiative

Yours sincerely

AJ Moore

Londonderry Primary School
Glenbrook Road · Newtownards · Co. Down BT23 4EY
Telephone: 028 9181 4325 · Fax: 028 9182 3827
A South Eastern Education and Library Board Controlled Primary School

International School Award

26 Feb 04 13:32 Robert Morrison 028 9071 9977 p.

SOUTH EASTERN EDUCATION AND LIBRARY BOARD

MOVILLA HIGH SCHOOL

INVESTORS IN PEOPLE
in Northern Ireland

Principal: B.R. Reilly, B.A., Cert.Ed.

Telephone: (028) 91812079 / 91812283
Fax: (028) 91814715

Donaghadee Road
NEWTOWNARDS
Co Down
BT23 7HA

12/2/04

Dear Sir/Madam,

Thank you for your letter received 10/2/04. The Science Department in Movilla High School would indeed be interested in the possibility of educational visits to your conservation area. To this end I hope to be able to visit on 20/2/04. Thanks again,

Yours sincerely,

Keith Anderson

(KEITH ANDERSON – SCIENCE DEPT.

-MAR-2004 14:57 FROM:CIVIL ENGINEERING 02890 663754 TO:

Queen's University Belfast

Dr. Gerald Müller
The Queen's University of Belfast
Civil Engineering Department
David Keir Building
Stranmillis Road
Belfast BT7 5AD
Tel.: 0044 2890 274517
Fax: 0044 2890 663754
Email: g.muller@qub.ac.uk

05.03.2004

To: Frank Brown
Strangford Lough Wildfowlers & Conservation Association
Glenvale Hall
45 Crawfordsburn Road,
Newtownards

Dear Frank,

as a lecturer in hydraulic engineering at Queen's University Belfast I would be very interested in the demonstration hydropower site you want to develop in order to have a 'live' power station for teaching purposes, and I am delighted to express my support for your project. In addition, we would appreciate the opportunity to use the 1.7m drop on your site to develop a research project funded by EPSRC. We are currently conducting a detailed study of breast shot water wheels as hydropower converters. Initial results on a 1:4 model of such a water wheel have been very encouraging, with efficiencies of 78 – 80% for a broad range of flow rates ($0.18 \leq Q / Q_{max} \leq 0.8$). This project would involve the construction of a 3.4m diameter / 7 kW power output water wheel prototype, and a detailed measurement programme (performance characteristics and long term power output). Your site would be ideal since both grid and web connection for power take-off and remote data acquisition would be in place. I would hope that such a low head power converter would also prove a valuable addition to your proposed development.

I am looking forward to hear from you soon

yours sincerely

Gerald Müller

Dr G Muller
Q.U.B. Civil Engineering

Appendix G - Electrical Schematic for Embedded Generator Linked to NIE System