Totara Valley Micro-Hydro Development

A thesis presented in partial fulfillment of the requirements for the degree of

Master of Applied Science

in Renewable Energy Engineering

Massey University, Palmerston North,

New Zealand

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2008

Abstract

This study focuses on the design, construction and operation of a distributed generation system based on micro-hydro technology.

The project is sited in the Totara Valley, a small rural community approximately 70km from the Massey University, Turitea campus, Palmerston North.

The Massey University Centre for Energy Research (MUCER) has a long history of renewable energy research within the Totara Valley community. This project complements these existing schemes and provides a foundation for future research into distributed generation technologies. The project encompasses the following objectives:

- to gain practical experience in the design, engineering and implementation of a distributed generation system in rural New Zealand;
- to evaluate contemporary micro-hydro technology and compare the performance of this equipment in a theoretical and practical context;
- to identify barriers that hinder the widespread adoption of micro-hydro systems in rural New Zealand;
- to develop a spreadsheet based life cycle costing tool.

The results from this study demonstrate that economic considerations are the fundamental aspect to be considered when assessing the long-term viability of these projects.

The viability of micro-hydro projects are primarily determined by four factors:

- the volume and head (height) of water available above the turbine site;
- the length and therefore the cost of the pipeline required for transporting water to the turbine;
- the legal and administrative costs involved in obtaining a resource consent to maintain access to the water resources;
- the prices received and paid for electricity.

Considerable charges were payable to the local authority to secure and maintain the right to harness the water resources at this site. This cost contributed considerable risk to the project and creates a significant barrier to establishing similar systems at other sites.

The reduction of resource consent charges to levels that fairly reflect the negligible environmental impacts of these projects would encourage the adoption of this technology and deliver benefits to rural New Zealand communities.

Cover image: Looking west down the Totara Valley, taken 200m from intake site June 2005.

Acknowledgements

The author would like to sincerely thank all of those who have joined and supported me in this interesting and rewarding project. I am grateful to have had the opportunity to work with you all and feel privileged to be involved in the development and construction of this project. In particular I gratefully acknowledge…

Dr Jim Hargreaves, Massey University: assistance with engineering, survey and construction

Prof. Ralph Sims, Massey University: Convener supervisor, sponsor recruitment and project oversight

Michael Lawley, Eco innovations: turbine supply, installation and technical advice

Ben Mc Queen, IRL: supply of Energy Recyclers Inverter, project sponsor

Tabitha Anthony, Horizons Regional Council: Assistance with Resource Consent

Andrew Hurley/Todd Mead, Main Power: Interconnection agreement management and project sponsor

Rachael Boisen, Massey University: Previous environmental report on the Totara Valley stream

The *Smith family* of Croftlea farm Totara valley Road for their neighbourly support

The *Poulton family* for their continued support of Massey University research in the Totara Valley and for allowing us access to their property and its natural resources to complete this project.

It is also with regret that I record the passing of *Mike Poulton (Snr)* during 2006. Mike kindly offered his property as the location for this project. Over the years Mike tirelessly supported Massey University research projects in the Totara Valley.

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1.0 Introduction

Throughout New Zealand there are many rural properties with water resources capable of supporting small-scale hydroelectric generation. Furthermore, these resources can be developed with minimal cost and with negligible effects on the environment.

Anecdotal evidence suggests that in recent years there has been considerable interest in small-scale renewable generation technologies, this interest is driven by the following factors:

1) continued electricity price increases have become an ongoing feature of the New Zealand electricity market. These price increases have been greater in rural and provincial areas compared to the bigger cities;

2) the removal of legislated protection of electricity supply to rural consumers in 2013. Some rural lines may be declared “uneconomic” and rural consumers will either be forced to pay for the maintenance of these lines or find alternative energy supplies;

3) concerns regarding greenhouse gas emissions and the benefits of renewable technologies. These systems offer a worthwhile contribution towards meeting New Zealand’s Kyoto obligations;

4) depleting fossil based resources, in particular natural gas;

5) the desire for consumers to secure a degree of self-sufficiency in their energy supply.

This project focuses on the design and construction of a Micro-Hydro electricity generation system and the benefits it offers the local community.

1.1 Objectives

This project encompasses several research objectives of the Massey University Centre for Energy Research (MUCER).

The project is designed to provide diversity in energy research opportunities in the Totara valley. It is expected that MUCER will attain practical experience in the design, construction and operation of a grid connected distributed generation system in rural New Zealand.

Furthermore the project seeks to identify the technical, administrative and economic barriers limiting the widespread proliferation of this technology.
A simple spreadsheet model has been written to facilitate analysis of the economic performance of these systems.
The final objective is to identify what commercial micro-hydro technology is presently available and assess the technical and engineering resources required to implement a small scale working system.
The project complements existing renewable energy projects managed by Massey University in the Totara Valley and provides a foundation for future research in the renewable energy sector.

1.2 Project Description

In early 2005 the author and Dr Jim Hargreaves from MUCER conducted an initial survey and feasibility study to investigate the establishment of a small (1 – 2kW) hydroelectric generating plant on the Totara Stream.
Three options were identified, all of these scenarios involved piping water from an elevated intake site down to a turbine site. After evaluating these options it was decided to proceed with a site offering a respectable 160m of "head" (The term "head" refers to the vertical height of the stored water above the turbine).
The project would entail the laying of 1300 metres of polyethylene pipe from the water source to transport water down to the turbine.
The water flowing through the turbine would drive an electric generator that charges a bank of batteries. To prevent over charging of the batteries a charge controller is to be
integrated into the system, its purpose is to divert any excess power into a "dump load". Power from the battery is then used to energize a power converter (Inverter) which is an electronic unit designed to convert the 50 Volt DC energy stored in the battery into a 230V AC format suitable for feeding into the national grid.

A pictorial layout of the system is depicted in Figure 2.

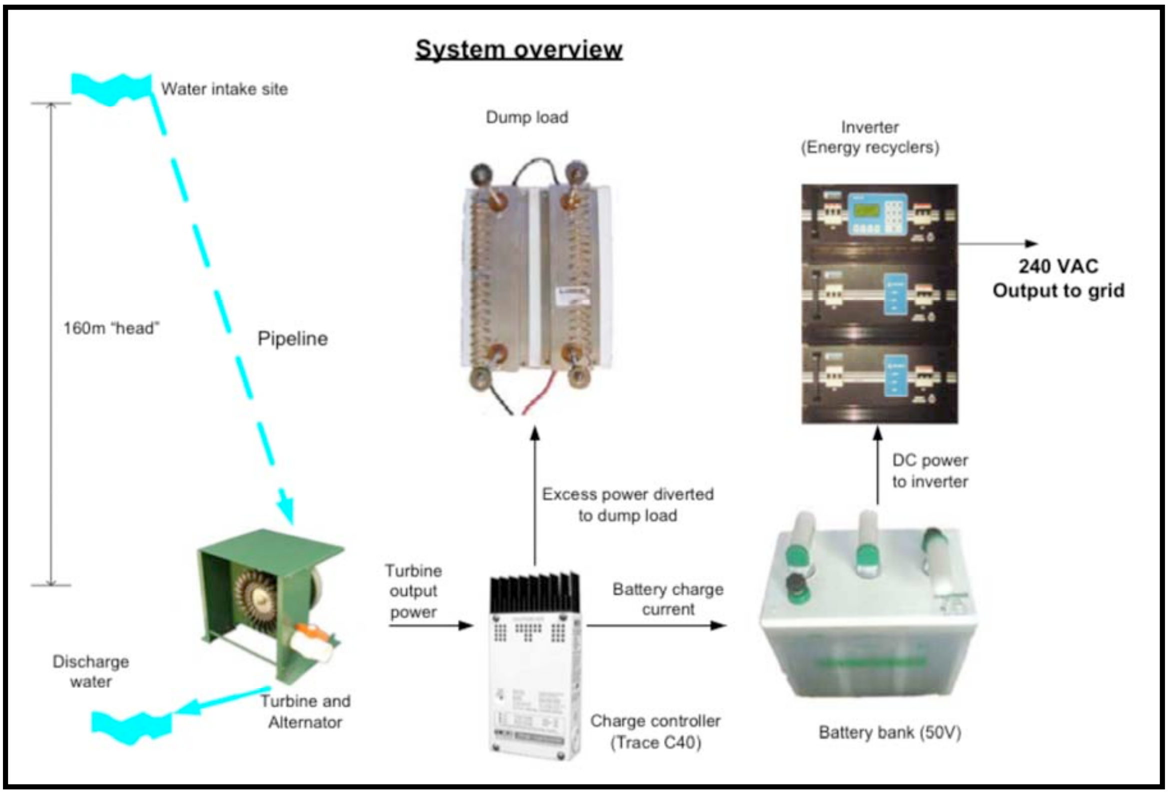


Figure 2 Final system layout selected from surveyed options

A New Zealand manufactured turbine of Pelton wheel design was selected together with its unique alternator and rectifier assembly to generate a 50VDC supply. Conversion of the DC supply to 230VAC and integration with the mains supply was achieved using a locally manufactured electronic inverter donated by one of the project sponsors. In January 2006 the project was successfully completed and began generating electricity. This paper documents the technical and economic decision making processes throughout the project and also discusses the logistical and administrative challenges that influenced the decision making process. Finally the project outcomes are evaluated and discussed.

1.3 Scope and Structure

This thesis deals with the technical, economic and practical aspects of a distributed generation project.

Specifically it presents a review of the background theory and continues with a more detailed description of the project design and implementation.

Throughout the text factors that impact on the design of the system and the necessary compromises that were accepted to make the project a success are discussed.

A financial analysis is included to determine the economic viability of the project and identify the main financial drivers of project success. Several scenarios are considered and the final cost of generated electricity is compared.

A commercial turbine was purchased for this project, therefore there is limited discussion on the design and construction of the turbine itself.

The scope of this study does not extend to examining the social impacts of the project.

However, an analysis of greenhouse gas emissions avoided is discussed in section 5.3 and an "Environmental Effects Report" is included in appendix 1.

The "Environmental Effects Report" presented in appendix 1 was necessary to gain resource consent for the project.

1.4 Map of Totara Valley site

Figure 3 illustrates the steep topography of the site and shows the pipeline route and points of interest.

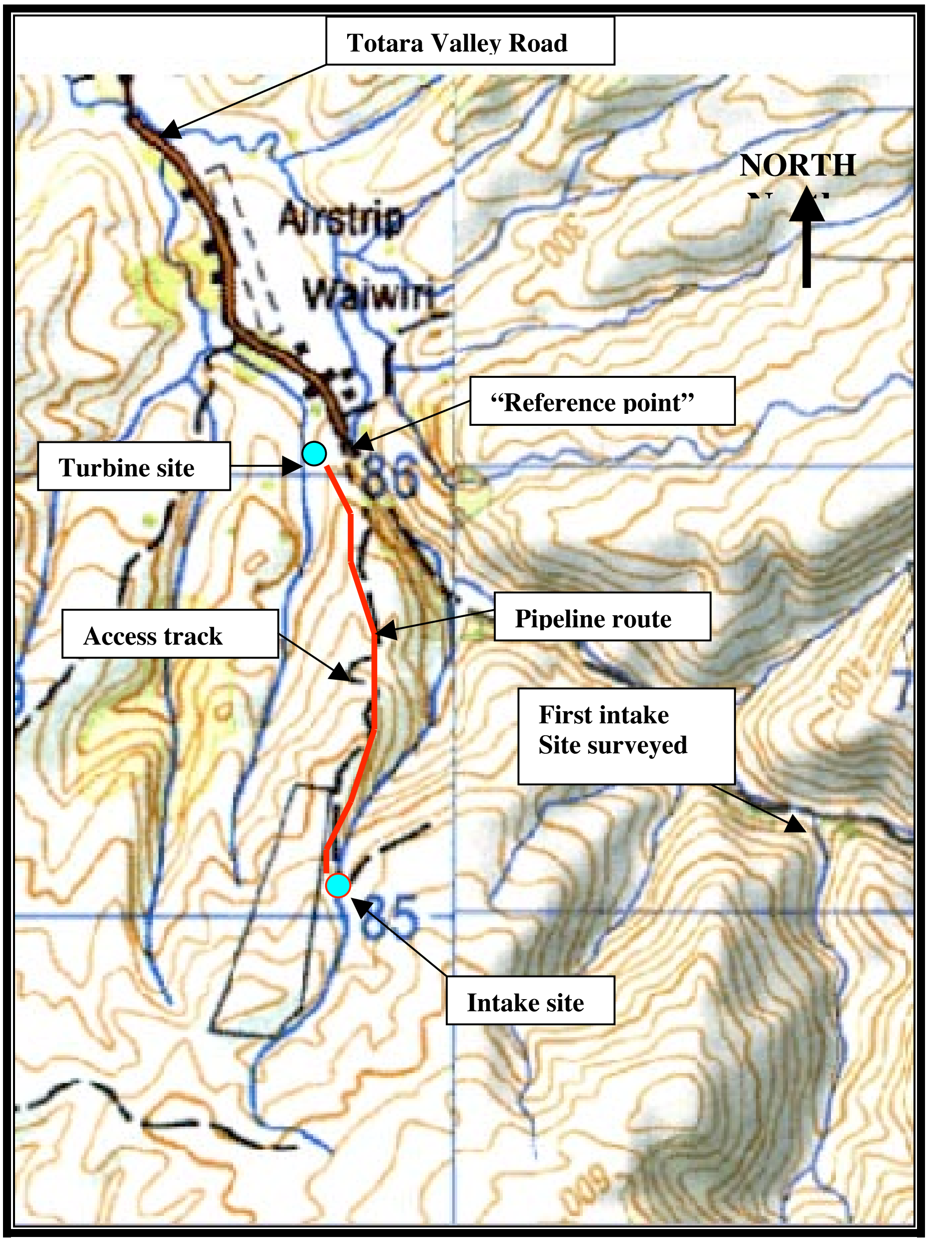


Figure 3 Site map depicting points of interest

Map courtesy Land information New Zealand (2006)

2.0 Literature Review and background theory

This chapter examines the background literature that was researched prior to and during this project. It is anticipated that that the literature research undertaken on this project may be useful to readers with an interest in Micro-hydro development. The literature review also puts into context this thesis within the framework of existing publications.

2.1 The case for Distributed Generation

The recent report "Get Smart Think Small" (2006) prepared on behalf of the Commissioner for the Environment makes a compelling case for the widespread implementation of distributed generation.
Advantages cited include:

1. making use of local renewable energy resources that are not suitable for large generators;
2. as many distributed generation (DG) systems resources are renewable they offer a path to reducing greenhouse gas emissions;
3. increasing the efficiency and security of the electricity network by spreading energy generation throughout the Network;
4. improving security and consumer control as end users are more self reliant;
5. introducing greater competition into the marketplace;
6. encouraging regional development and creating jobs for designers, manufacturers and installers;
7. raising individual awareness about energy that also increases energy efficiency awareness;
8. improved health through warmer homes and lower running costs.

This project supports these observations. The resources available in the valley are entirely unsuitable for large-scale development, however a variety of small renewable projects are supported within the Valley with negligible effects on the environment.
The Totara Valley projects have improved awareness about energy issues in the local community and will provide a degree of independence and local control over their energy supply.

It is critical that small scale distributed generation systems take advantage of renewable resources in preference to imported fuel supplies. This factor disassociates electricity generation from the drawbacks of fossil fuel based technologies.

In addition to reducing greenhouse emissions renewable systems can be engineered to run indefinitely without depleting the resources that power them. They therefore offer true sustainability and security for users.

Renewable resources are primarily a consequence of radiation from the sun and include direct solar energy (thermal and photovoltaic), wind energy (a result of uneven heating of the earth's surface) and hydro (taking advantage of natural evaporation and precipitation). Non-solar based renewable energy such as tidal and geothermal resources offer predictable and consistent output.

Boyle (2004) highlights the importance of "diversity of supply". In essence for optimum integration with the grid it is important that distributed generators are well dispersed throughout the grid and feature a range of technologies. This reduces the problems associated with the intermittent and localized nature of renewable resources.

For example if the sun is obscured by clouds in Nelson or the wind stops blowing in Palmerston North it is likely that renewable based generators in other parts of the country will experience more favourable conditions and continue contributing to the network.

Finally distributed generation offers the advantage that electricity is often generated where it is required, this is particularly true with co-generation projects where electricity and heat energy may be required. This reduces transmission losses and minimizes the possibility of constraints due to inadequate transmission infrastructure.

2.2 Legal Background – The Resource Management Act(1991)

Before discussing the consent application a brief introduction to the Resource Management Act and the supporting local body regulations is appropriate.

The legal status of these projects is covered by the Resource Management Act 1991 (RMA). Appropriate council bylaws are embodied within the Regional and District Plans that enforce the provisions of the RMA (Horizons Regional Council, 2005).

Previous projects completed by Massey University in the Totara Valley were land based activities and were administered by the Tararua District Council.

Under the provisions of the RMA the administration of water resources and the beds of streams, lakes and rivers is vested with the Regional Councils. Consequently the author was required to deal with the Horizons Regional Council to gain approval for this project.

In summary the Act requires that local bodies are required in their district/regional plans to specify what activities are allowed in particular geographical zones under their control. This is a long process involving considerable consultation with the community that culminates in the development of a District Plan.

Activities included in the District plan are divided into several categories as outlined in the Resource Management Act (Ministry for the Environment, 1991).

In summary they comprise four specific types of activities.

1) *Permitted activities*, these are activities that must be allowed in a zone and councils are required to issue a consent to applicants engaging in these activities. For example building houses in an area zoned for residential development.

2) *Controlled activities*, are activities that must be allowed in an area however the local body may impose controls on the activity.

2) *Discretionary activities*, are only permitted at the discretion of the local body and are often subject to conditions. Discretionary consents can be non-notified where the activity is deemed to be of little consequence to the public interest and consent is granted subject to conditions being met. Alternatively Discretionary consents can be "notified" which entails a lengthy process of public consultation by the applicant, at the applicant's expense. It is at this stage objectors to the project can appear and considerable litigation can result if a compromise solution cannot be found.

3) *Non Complying activities*, are those that are not permitted in the regional plan and the local Authority cannot authorize them.

The Horizon's Regional Plan makes no provision for Micro-Hydro Schemes. However the plan does allow for the daily abstraction of up to 50 m^3 (cubic metres) of water as a permitted activity. (Horizons Council, 2005). This project required a maximum abstraction rate of 2 litres per second which equates to 172.8 m^3 of water per day and was therefore deemed a discretionary activity requiring two consents.

A resource consent was required for the abstraction of water from the stream and a further consent was deemed necessary for the discharge of this water back into the stream.

A further consent will be necessary if the project involves the construction of a Weir or Dam.

As a requirement of the consent the author was required to seek approval for the project from the landowners, neighbours, The Department of Conservation, and Fish and Game New

Zealand. An assessment of Environmental effects report was also submitted with the resource application.

All of these documents together with the consent notification received from the Horizons Regional Council are included in appendix one of this thesis.

2.3 The Electricity Governance Regulations 2007

The Totara Valley project was completed in 2006 at a time of uncertainty for small-distributed generators. The system was connected to the Scanpower owned distribution network based on a "gentleman's agreement" modeled on previous transactions between project sponsors Mainpower/IRL and Scanpower management.

In September 2007 the *Electricity Governance (connection of distributed generators) regulations* came into force (Ministry of Economic Development, 2007). The regulations do not apply retrospectively to earlier installations (Part 17.1) and therefore the Totara Valley project will remain operating under its existing agreement.

However it is appropriate to outline the new regulations, as readers will be faced with this new legislation if they intend to connect to the grid.

The regulations require distribution companies to connect distributed generators to their networks providing generators meet certain criteria.

The conditions encompass both technical and administrative requirements.

In summary the distributed generator's installation must adhere to several technical standards. Specifically the Australian/New Zealand Wiring Rules NZ/AS3000 (StandardsNZ, 2007). Available at www.standards.co.nz. This standard is not specifically aimed at distributed generation projects. It is the foundation document that specifies minimum electrical wiring standards applicable to all electrical installations within New Zealand and Australia.

In addition equipment is also required to conform to the AS 4777 standard (Standards Australia, 2007) available at www.standards.com.au. This document specifies requirements for Grid connection of energy systems via inverters. The provisions of this standard also apply to grid connected installations that do not include inverters.

In addition to these requirements the distribution company will typically have technical requirements that must be met. Typically this includes a lockable isolating switch similar to the one installed on the Totara Valley installation.

The regulations impose different requirements on the parties depending on the capacity of the proposed system. The process is somewhat less onerous for generators proposing less than 10kW maximum capacity.

The regulations also specify the maximum fees that may be charged by distribution companies. Distribution companies are now required to provide application forms free of charge, a schedule of fees, standardized terms and conditions of connection, a policy statement and applicable rules. Most distribution companies have put these on their web sites. "Scanpower" the distribution company that operates the network in the Totara Valley was contacted regarding their connection policies. "Scanpower" CEO Lee Beetles responded to the author's enquiry and advised that "Scanpower" are still working on this. As the smallest distribution company in NZ (they have around 5000 consumers) the Totara Valley project is the only contact they have had with a small-distributed generator.

The final requirement is that the distributed generator must have an agreement with a retailer to purchase surplus electricity before the distribution company will accept connection. The retailer must already be operating on the distributors network.

As a consequence of Government intervention many of the distribution companies have published distributed generation "kits" on their websites.

An information brochure from "Vector Ltd" is a particularly good example and is included in the appendix 2 to illustrate the new requirements.

2.4 Categories of water turbines

Over the centuries many different turbine designs have been developed and refined for specific applications. These turbines can be grouped into two principles of operation.

1) Reaction turbines The reaction turbine is better suited to low head applications. Typical examples are the Kaplan turbine and Francis turbine. Francis turbines are in widespread use. This can be attributed to their wide operating range and their capacity to be easily scaled. Reaction turbines operate fully submerged and rely on hydraulic forces exerted on the shaped blades as the water flows through them. In contrast to an impulse turbine, the flowing water is simultaneously acting on all of the blades rather than a few of the cups/blades at any instant as occurs in an "Impulse" turbine. Reaction turbines exhibit a water pressure difference between the input and output of the turbine. The energy extracted from the moving water is proportional to the pressure difference across the turbine and the magnitude of the flow through the turbine. Consequently Reaction turbines can utilize some of the suction "head" as the water drops away from the turbine.

For a given head reaction turbines will typically run faster than an impulse turbine. (Wilson, 1962)

2) Impulse turbines Typically operate at higher heads than reaction turbines. Examples include the Pelton Wheel and Turgo turbine. In principle a jet or flow of high speed water is directed at the turbine runner and the water releases some of its kinetic energy as it impacts onto the runner. This impacting water exerts a force on the runner that causes it to rotate. The water then drops away from the turbine runner and is discharged.

The Impulse turbine is typically run at atmospheric pressure and cannot operate submerged in the flow of water. Consequently selecting a flood free site is critical.

2.5 Review of background theory

The turbine selected for this project is a Pelton Wheel design. A feature of the Pelton wheel is that it requires a high head for maximum efficiency and it will operate at relatively low flow rates. The runner of a Pelton Turbine typically rotates at high speed making it well suited to driving many types of electricity generators.

All of these attributes make it ideal for this project. Table 1 provides a guide to the selection of an appropriate turbine type for a typical site.

Turbine Runner	High Head (more than 100 m / 325 ft.)	Medium Head (20 to 100 m / 60 to 325 ft.)	Low Head (5 to 20 m / 16 to 60 ft.)	Ultra-Low Head (less than 5 m / 16 ft.)
Impulse	Pelton Turgo	Cross-flow Turgo Multi-jet Pelton	Cross-flow Multi-jet Turgo	Water wheel
Reaction	—	Francis Pump-as-turbine	Propeller Kaplan	Propeller Kaplan

Table 1 ***Selection of Turbine type (courtesy Natural Resources Canada)***

Publications on Micro-Hydro technology were found to be particularly prevalent in journal format, whilst most textbooks focused on larger hydroelectric schemes. However many of the design principles discussed in texts are scalable and are therefore equally applicable to micro-hydro projects. In particular Boyle (2000) presents a concise theoretical background based on first principles that proved useful in the design of this project.

The *Pelton Turbine Installation Manual* (Lawley, 2004) also proved a useful reference that provided both practical and theoretical advice regarding the implementation of micro hydro systems.

The primary objective of a hydro turbine is the conversion of kinetic energy embodied in falling water into useful mechanical energy that can be utilized to rotate a turbine “runner”. Subsequently this mechanical energy can be harnessed to drive an electric generator, mill or water pump.

The application of water turbine technology is not new and has been in widespread use for several centuries. Early applications included powering machinery, milling crops and ironically pumping water. Our ancestors quickly realized that water is a particularly heavy substance and observed its considerable power as it flowed over waterfalls. They no doubt also observed that water was conveniently carried to high altitudes by the natural cycle of evaporation and precipitation.

The mechanical output available from a hydro turbine is proportional to the flow rate through the turbine. Greater flow rates imply that a greater mass of water is passing through the turbine and the resulting total kinetic energy available will be greater. Output is also proportional to the height the water falls before passing through the turbine. This is known as the static “head”. In practice the actual “head” available to the turbine is reduced somewhat by the friction of the water flowing within the pipes and joints. Clearly, the greater the height the water “falls” the greater its speed or static pressure (if enclosed in a pipe) and therefore the more energy it embodies. Finally the conversion efficiency of the turbine will also impact on the mechanical power output.

The mechanical output power available from the turbine may be summarized in the formula

$P = Q \times h \times g \times \eta$ (1) (Boyle, 2000)

Where P is the mechanical power output of the turbine in Watts;

Q is the mass of the water passing through the turbine in Kg/second. As water weighs 1 kg per litre Q is conveniently the flow rate in litres per second;

h is the effective head available at the turbine in metres;

g is the acceleration due to gravity ($9.8\ ms^{-2}$);

η is the conversion efficiency of the turbine.

This makes sense, as the power available from a water turbine is proportional to the amount of water flowing through the turbine, and also proportional to the difference in pressure (height) between the water inlet and output of the turbine.

We can therefore expect that doubling the flow rate through the turbine will double the power output. Similarly doubling the head (height) of the water flowing into the turbine will also double the output power.

The calculation of several other system parameters is necessary to complete the design process. In summary these parameters will be examined:

1. calculation of the pipeline flow velocity;
2. calculation of the expected system output power;
3. determination of the water velocity upon exiting the turbine jet assembly;
4. derivation of the optimum jet size;
5. estimation of the rotational speed of turbine ;
6. calculation of the head losses attributable to friction within pipelines .

To preserve continuity these parameters are discussed in detail in section three of this document.

As highlighted above a contributor to reduced efficiency is the losses resulting from friction between the flowing water and the internal surface of the pipe used to transport the water. This pipe friction reduces the overall head available at the turbine and therefore reduces the expected output power.

It is dependent on the flow rate, the internal diameter of the pipe and the surface roughness of the inside surface of the pipe.

Three methods of deriving the magnitude of this loss are discussed and compared in the text.

The simplest method is to use tables that plot head loss against flow rate for various sizes of pipe. Tables are typically available from reputable pipe manufacturers although they are becoming increasingly scarce particularly for new products.

In recent years there has been a trend towards web-based tools and several online programs are available to deal with this aspect of design. Iplex Ltd the pipe suppliers for this project have a web based calculator (available at www.iplex.com.au) that was evaluated and is presented in the discussion section of this report. Specific details are provided in Appendix three (Iplex, 2007).

Finally the Australian Pump Manufacturers Technical Handbook (APMA, 2004) recommends using the "most widely used" Hazen and Williams formula that offers a mathematical approach to this problem.

The two methods are compared and discussed in more detail in sections 3.8 and 3.9 of this thesis.

The Canadian Government's Department of Natural Resources also offers some excellent information on micro hydro projects. In particular their comprehensive "Micro hydro guide" provides a good overview and can be downloaded at http://www.builditsolar.com/Projects/Hydro/hydro.htm

Finally two renewable energy journals provided additional practical help, although because of their target audience these publications focus on the practical aspects of installation in preference to an academic approach.

In particular the American "Home power" journal featured several articles on installing micro hydro systems in issues #103, #104 and #105. Back copies can be purchased from their web site www.homepower.com

A basic guide to micro hydro is also available to download for free at http://www.homepower.com/basics/hydro/

However these articles are now somewhat dated and newer journals such as the Australian Alternative Technology Association's publication "Renew" featured a more recent micro hydro buyers guide in their issue # 92, (Oct – Dec, 2005) edition. Interested readers will find it available for purchase at www.ata.org.au

Whilst these journals are not unduly technical they do provide a good summary of contemporary micro hydro technology and identify what technology and range of turbine sizes are now commercially available. They also provide a good reference of current industry practices and provide a benchmark for performance that can be expected from these systems.

2.6 System maintenance

An area not considered until after construction of the Totara valley project was completed is the reliability and maintenance requirements of renewable energy systems.

The watershed report "Renewable energy in Remote Australian Communities" (Lloyd et all 2000) provides a timely reminder of the importance of implementing effective maintenance regimes for renewable energy systems. Their research found that only 68% of the renewable systems surveyed were actually operational at the time of survey and there was subsequently considerable dissatisfaction with renewable energy systems in rural Australia.

In particular many renewable systems that are installed in remote areas incorporate specialized technology. This factor necessitates sending specialist staff to repair systems to remote locations. Clearly the costs involved are considerable and the delays encountered in repairing non-operational systems can be frustrating for system users.

Soon after completion this project demonstrated the truth of these findings.

Two failures, requiring specialist attention have resulted in the shutdown of this system. One failure involves a software fault in the Inverter. This fault will require the assistance of a specialist sponsor to repair. The other problem concerns a bearing failure due to water ingress within the turbine assembly itself. The manufacturer now markets a kit to deal with this problem.

Accordingly an allowance has been made in the financial analysis of this project to cover both scheduled maintenance and unscheduled eventualities.

3.0 Project materials and processes

3.1 Site Survey

On 26th of April 2005 Dr Jim Hargreaves (MUCER) and the author conducted an investigation of the micro hydro potential of the upper Totara Valley Stream. Three potential intake sites were identified and the merits and challenges associated with each site were examined.

In addition two turbine sites were identified and these are also evaluated.

Distances were measured using a measuring wheel of the type typically used for measuring athletic tracks and basic surveying. Distances were measured during the walk up to proposed intake sites and then compared with readings taken on the way down.

Altitudes were measured using a Barometric Altimeter similar to the instruments used by mountain climbers. The unit used was a “Loft Sports” model purchased for this project, several measurement were taken at each site and compared with map contours to confirm the integrity of readings. Specifications of the unit are included in appendix four.

A reference point was chosen at the corner post at the end of the road next to the woolshed. The location of this point is marked on the site map shown in figure 3.

Defining this site as a reference point enabled us to make relative altitude measurements and calculation of pipe distances to the intake sites.

The Totara stream was surveyed a total of 2.3 km upstream from the reference site.

One potential intake site was identified on the main Totara Stream and two alternative intake sites were located on tributaries feeding the Totara stream.

3.2 First intake site

The first site found was at a small waterfall on a tributary which confluences with the Totara stream 1661m from the reference site. The altitude of the waterfall at this site was 63m above the reference point. This site offered the following attributes:

1) The top of the waterfall was approx 8m above the Totara stream yielding a total head of 63m to the reference site;
2) The site would require 1700m of pipe to construct the penstock(intake pipeline);
3) Access was very difficult and the area was over grown with thorny bushes;
4) Flow of the side stream was not measured but was estimated to be in excess of 15 litres/second.

Figure 4 Intake site 63m above the reference site

Assessment of first intake site.

We found that nearly 40m of the total head at this site was attained in the last 400m of pipe. Therefore a considerable part of the required pipeline would contribute little towards the total static head and therefore output from this site.
In view of the minimal pipe savings and the difficult access to this site it was decided an intake site further up the track was a better choice. This intake site was therefore discounted as an option.

3.3 Second surveyed intake site

A second intake site was found 2174m upstream from the reference point approximately 50m distant from a ford across the Totara Stream. A plot of pipeline pressure against actual measured distances is shown in figure 5.

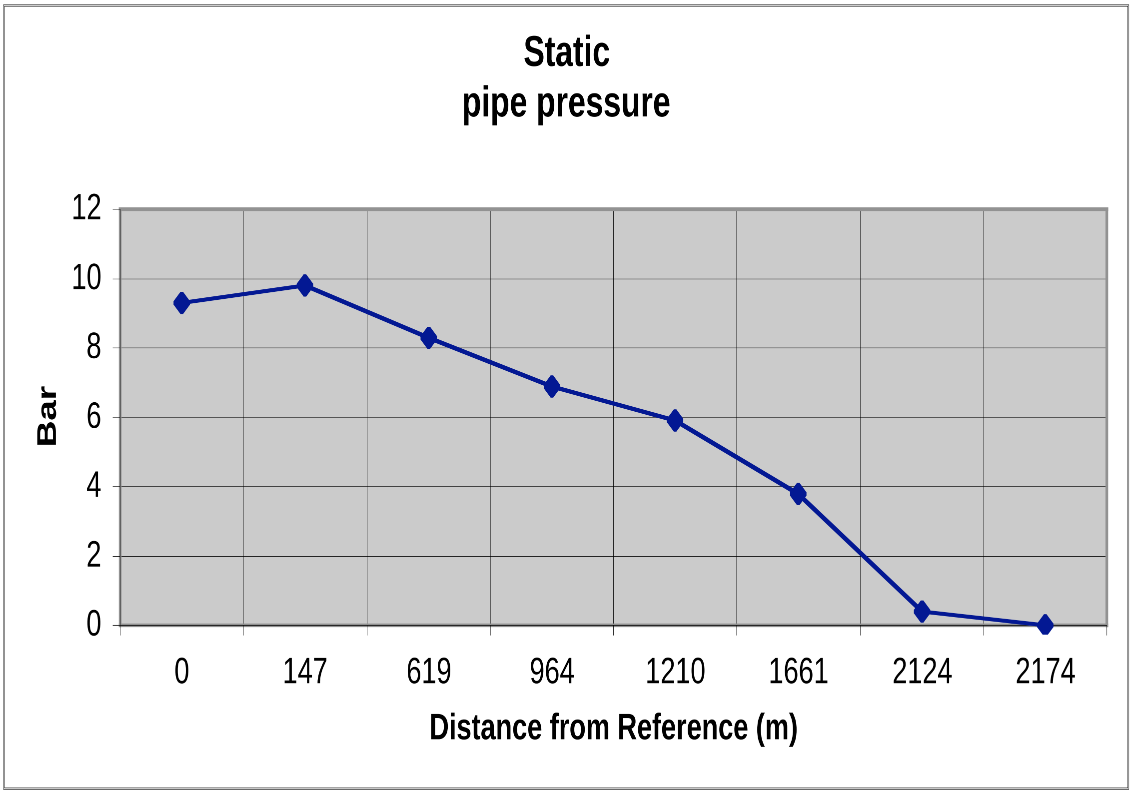


Figure 5 Expected pipeline pressure profile of 93m site

This site offered the following advantages:

1) The altitude increased considerably over the last part of the survey and the Totara streambed attained an altitude of 89m at the ford. A total static head of 93m to the reference site was possible from this site;

2) Good reliable flows were evident and we estimated flows to be in excess of 30 litres/sec. These have also been previously researched and documented in previous studies (Boisen, 2005);

3) Access was good for both weir construction and running a pipeline.
However this is the most distant site and would require purchasing and installing 2170m of pipe to reach the nearest turbine site.

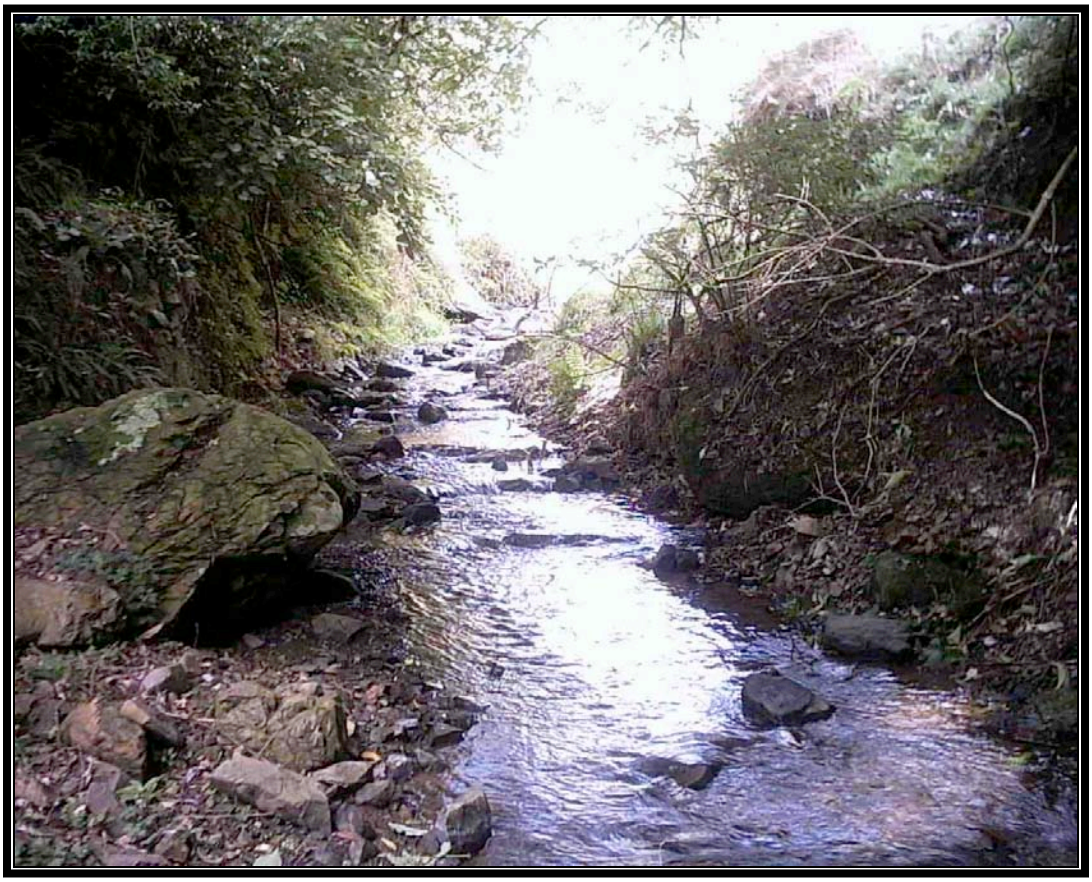


Figure 6 Second Intake Site surveyed

Assessment of intake site two.

Initial calculations show that assuming a 2 l/sec flow and 55mm ID pipe the following theoretical output power is available (from equation 1, page 13)

$P = Q \times h \times g \times \eta$ (1)

2L/sec x 9.81x 93m x 0.7(efficiency factor) = 1277W shaft power.

However this does not take into account the frictional losses within the pipe. Eco-innovations loaned the author a spreadsheet model, “Joe’s pipe calc’s” to quickly evaluate the pipe losses (Cole, J. 2005). Their previous experience has shown that this spreadsheet yields accurate results. Several iterations of the spreadsheet model were run to construct the chart depicted in figure 7. From the attached graph it can be seen that output peaks at 2L/sec flow and we can expect around 830W at the turbine shaft after pipe losses are accounted for.
Assuming 70% generator efficiency this equates to around 581W of electrical output.

Electrical output could be increased to 950W by employing a larger 66mm ID pipe, however the pipeline cost is more than doubled. If more output power is required a second 55mm ID (63mm Outside diameter) pipe run is a more cost effective option.

Numerous iterations of the spreadsheet were run to compare the expected output available from various pipe sizes and therefore obtain the most cost effective solution

The result of this work is summarized in Figure 7 below. Note the limitation in mechanical output power due to increased frictional losses at higher flow rates.

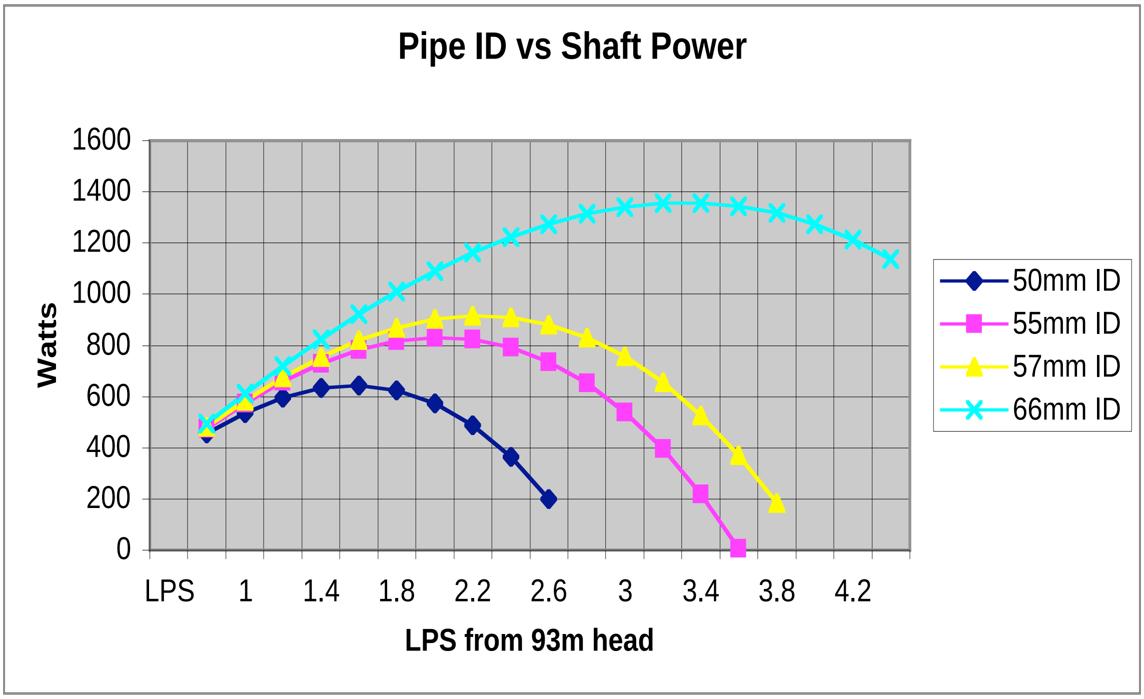


Figure 7 Expected output from the 93m site with various pipe diameters.

3.4 Intake site 3

On the farmer's recommendation a third intake site was examined. This site was at the top of a waterfall identified as a possible site on our first visit but discounted due to difficulties finding a route for the pipeline. With the farmers help it was confirmed that it was indeed possible to run a shorter pipe on the side of a steep ridge directly down to the turbine site.

This intake site offered the following advantages:

1) A considerable 165m of head;
2) Small flow rates (approx 1.5 l/s) would be possible as a consequence of the high head;

3) Easy access with a track crossing the intake site at the top of a waterfall;
4) Easier access to lay pipe and some protection for the pipe compared to other options;
5) A shorter 1300m pipe run to nearest turbine site;
6) Technical difficulties encountered with this site may be of academic and practical interest to project stakeholders.

However the site does presents some difficulties:

1) The cost of pipe would be greater than expected as the higher pressures involved would require the use of high-grade pipe;
2) The turbine manufacturer has advised that at this pressure it is possible to experience erosion problems with the plastic buckets employed on the Pelton wheel;
3) We are unsure of the reliability of the turbine assembly at these pressures;
4) The pipe would need to cross a saddle at 152m relative altitude. This involves installation of the pipeline across a steep hillside to maintain a steady gradient on the pipeline (Depicted in Figure 1);
5) There are safety concerns with water discharging at approx 1600kPa at the turbine site;
6) The flow of the stream during the dry season was measured at 9 litres/sec. Although the farmer assured us this stream never dries we do not have any reliable data on flow rates. This may have implications when seeking resource consents.

Figure 8 The intake would be installed at the top of this waterfall

Assessment of third intake site. (160m waterfall site).

In view of the considerable static head and limited flow available the 51mm ID HDPE pipe was initially thought to be the only practical option here. This pipe is much more expensive than the MDPE used on the other sites.

To take advantage of this 160m head a special turbine designed to operate at these pressures would need to be purchased. The cost of this unit is expected to be considerably greater than the cost of a “standard” turbine.

During our initial survey some preliminary computer modeling was done to estimate the expected output from the 160m site. Initially 50mm outside diameter (OD) pipe was selected for this project. However the additional cost of the 63mm (OD) product was found to be insignificant and it offered considerably lower head losses and greater flexibility for experimentation.

Figure 9 depicts this early project model. It has been constructed by plotting iterations of the spreadsheet site calculator supplied by the turbine manufacturer. Critically these calculations are based on a 160m head and 63 mm OD pipe. The resulting chart clearly illustrates the increasing output possible with increasing flow, until a point is reached where the limitations of friction within the pipeline become significant and output decreases. The model shows mechanical output power and assumes 70% mechanical efficiency.

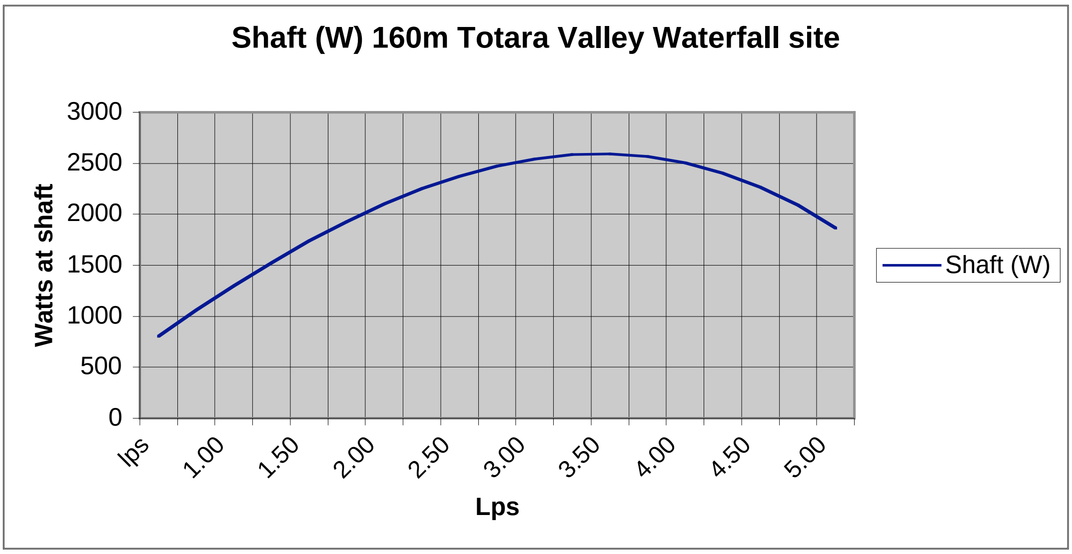


Figure 9 Theoretical turbine output power plotted against water flow

3.5 Selection of Intake Site

At a planning and evaluation meeting at the Massey Campus it was decided to proceed with the third intake site recommended by the landowner.

This site was chosen because it offered several unique attributes:

1) A challenging high head site;

2) The topography between the turbine and intake site is very steep and offered considerable challenges when laying the pipeline;

3) A small flow rate (1 – 3 litres /second) commensurate with an acceptable output power (around 1kW) due to the high head available;

4) The small flow rate would minimize environmental effects and also allow the use of a relatively narrow bore pipeline;

5) Straightforward access to most of the proposed pipeline as the route runs close to existing

farm tracks;

6) As the water supply was a tributary it would have minimal environmental impact on the main Totara Stream;

7) Finally, the technical difficulties encountered with this site offered both academic interest and practical challenges to the project.

Originally it was expected that a small weir would be built to provide sufficient depth of water to fully submerge the intake assembly. However the cost and difficulty of obtaining a third resource consent to dam the stream was prohibitive. Furthermore construction of even a small dam would involve considerable civil works that would further impact on the cost of the project.

After considerable discussion and referral to the literature (Lawley, 2004) the solution depicted in figure 10 was suggested. “Eco innovations” has constructed similar intakes and were confident that this arrangement could be successfully implemented on this project.

The assembly consists of a small stainless steel chamber sunk into the streambed with a grille at the top to allow water to drop into the chamber. Critically the intake grille is mounted at a 45-degree angle to allow debris to be flushed off the surface of the grille. The device is therefore self cleaning and is designed to minimize maintenance visits.

The assembly was adopted and subsequently installed in a small pool at the top of a waterfall.

The diameters of the holes in the grille are deliberately smaller than the jet diameter to ensure any particles that may block the jet do not enter the system. A jet blocked by a stone in the pipe would be catastrophic, as the sudden reduction in flow can cause a substantial surge in pipe pressure, which would almost certainly rupture the pipeline.

Figure 10 The intake assembly shortly after installation

After six months the vegetation had re-established itself and the white valve assembly remains as the only visible sign of disturbance. The intake assembly has proven to be self cleaning and trouble free.

3.6 Choice of turbine site

Two sites for housing the Turbine and generator were identified.

The first of these sites was on a short distance from the reference site at the location of a disused sheep dipping station. A pump and small shelter are still present on the site.

This site offered the following advantages:

1) A 3-phase power line is already in place to the shed that previously powered the now disused pump. This feature offered considerable cost savings as it offered an existing connection point into the electricity grid;

2) The site is an acceptable distance from the nearest two houses to avoid any potential noise issues from the turbine;

3) Vehicle access is good;

4) A small stream is adjacent to the site facilitating straightforward discharge of water back into the Totara Stream;

5) The site appears to be relatively safe from flood damage.

Figure 11 First Turbine Site (Site selected for project)

However the site does present the following issues:

1) The existing pump is 3m above the reference site and is 8m higher in altitude compared to the alternative turbine site. Therefore there is a small head loss;

2) A small shed would need to be purchased, as the current structure is not structurally sound.

A second turbine site was identified behind the tractor shed on the Totara Stream side of the road, a short distance past the last house. This site offers the following advantages:

1) It is situated at –5m altitude giving an 8m head advantage over the other site;

2) It is close to the Totara Stream, allowing straightforward discharge of water;

3) Offers excellent access;

4) The site offers good safety margins for flood damage;

5) Good noise isolation from nearby homesteads.

Figure 12 Second turbine site option

However:

1) A 47m pipe would need to be laid across the paddock to discharge the water back into the stream;
2) A shed and foundation would need to be built;
3) One span of power cable would be required, as the nearby tractor shed is not connected to mains power**.**

Figure 13 Turbine shed during construction

The small stream and discharge pipe (white PVC) are clearly visible. The pole to the right of the turbine shed already has power connected to the white distribution box. The black polythene line running across the paddock transports the high-pressure water collected at the intake site.

As a consequence of the decision to proceed with the 160m head intake site one of the turbine sites became a clear choice. The decision to choose the first turbine site surveyed was driven by the following factors:

1) The farmer indicated he preferred this site as it was out of the way and unlikely to interfere with farming activities;
2) A power line and pole was already installed on this site as it was the location of a disused sheep-dipping pump. This offered considerable economies, as no new lines would be required;
3) The site was well located relative to the proposed intake pipeline and offered savings of around 200m of pipeline compared to the alternative site;
4) It is far enough from inhabited buildings to avoid potential noise problems;
5) Vehicle access is possible in good weather;
6) A small stream adjacent to the turbine provides an ideal spot for the discharge of tailrace water.

3.7 Pipeline Design

In view of the isolation of the site, the length of pipeline required and the budget for the project, plastic pipe was an attractive option. The pipe proved easy to transport and could be physically carried and installed over the difficult terrain.

The pipe chosen is intended for agricultural irrigation and is already in widespread use around the farm. It therefore would not look out of place. The pipe is manufactured from medium density polyethylene (MDPE) and is relatively inexpensive when compared with other options.

Figure 14 63mm MDPE agricultural pipe used for the "Penstock"

Polyethylene pipe is available in several different pressure ratings. This proved important for our project as the high grade (16 bar pressure rating) pipe was $6.86 per metre in contrast to the standard grade (6.3 bar pressure rating) at $2.48 per metre.

The pressure within each section of the pipeline progressively decreases by approximately one atmosphere as it rises each 10m in altitude. Therefore considerable economies were possible during construction of the pipeline as almost half of the pipeline could be constructed using the lower grade pipe. A graphical summary of the pipeline pressure and grade transitions from PN6.3 through to PN16 is depicted in Figure 15. We also confirmed that this type of plastic is stable when exposed to UV light. A copy of the manufacturers specifications for this range of polyethylene pipe is included in appendix five.

Finally an excellent range of compatible joiners, valves and fittings is available for this type of pipe and these fittings are suitable for use on all of the different grades used. To ensure joiners and other fittings are compatible across the range of pipe grades the external diameter of the pipe is a constant 63mm. A gate valve was specified at both ends of the pipeline to accommodate shutting the system down. The choice of a gate valve in preference to a ball valve prevents sudden interruption of the flow that would cause undesirable pressure transients in the pipeline.

The pipeline route was surveyed to ensure a constant descending slope was maintained as much as possible. This was desirable to prevent air pockets from accumulating in the pipeline. Apart from laying the pipeline around a knoll near the intake the remainder of the line was run along fence lines in such a manner as to minimize its visibility. Much of the installation was on steep terrain and “warratah” stakes were used to support the pipeline along these sections. The pipeline crossed farm tracks on two occasions and was buried at these crossings to prevent damage from passing vehicles. The installation of the pipeline involved four people and took 2 days to complete.

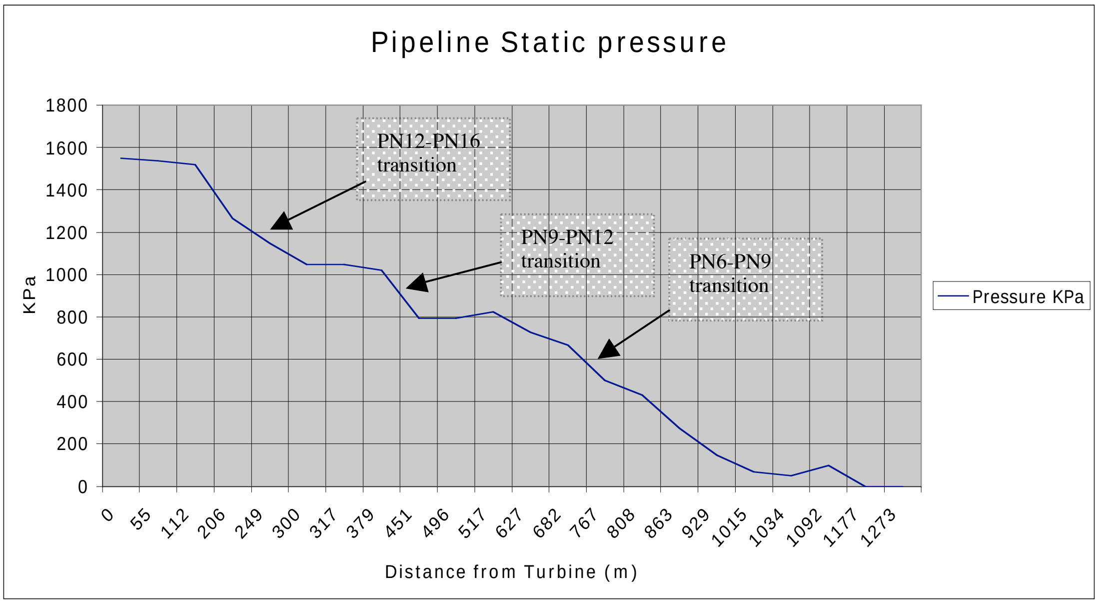


Figure 15 Graphical summary of pipe grade transitions and pressure profile

A further factor to consider are the losses caused by the friction of the water against the inside surface of the pipeline. This is called "flow resistance" or "head loss". Fittings such as joins, bends and valves also contribute additional flow resistance into the system. These parameters are tabulated in appendix 3 and are used as a basis for the flow resistance calculations below.

3.8 Calculation of Head loss

From calculations summarized above and detailed in Appendix 3 the required length of each grade of pipe is established. The next step is to quantify the head loss resulting from the friction between the flowing water and the internal surface of the pipe. The different grades of pipe have slightly different internal diameters and therefore the flow velocity and flow resistance are slightly different. Consequently the head loss for each section of the pipe will need to be calculated separately and then summed to arrive at the total head loss for the pipeline. The lengths and expected head losses are tabulated for each section of the pipeline in Table 2. The head losses are calculated using a web design tool available on the "IPLEX®" website (www.iplex.com.au) and details are presented in appendix 3. Head loss for the joiners and gate valves could not be obtained directly from the manufacturer. However a document published by Brisbane Polytech (2000, TAFE) suggests an allowance of 0.5m head loss for each pipe joiner and 0.7m for each gate valve should be made. These were the allowances used in this calculation.

Grade	**Quantity(m)**	**Head Loss(m)**	**Velocity(m/s)**
PN6	573	7.0m	0.80
PN9	250	3.6m	0.84
PN12	200	4.2m	0.98
PN16	250	5.2m	0.98
Pipe joins	14 joins@0.5m	7m	
Gate valves	2 gate valves@0.7m	1.4m	
Total	**1273m**	**28.4m head loss**	

Table 2 ***Calculation of total pipeline head loss using website tool***

Therefore the Effective (Net) head available at turbine

$\therefore$ Net Head = Gross head – hydraulic losses

$\therefore$ Net Head = 160 – 28.4m = 131.6m @ 2 l/s flow

3.9 Alternative method of calculating frictional loss of Pipeline

As a comparative exercise a mathematical solution (Hazen and Williams formula) for head loss evaluation is discussed in the *Australian Pump Technical Handbook* (APMA, 2004). This method is presented below and results are calculated as follows

Where H_L = Head loss per 100m of pipe

Q = flow in litres per second (2 litres/sec)

d = internal diameter of pipe in mm (55.2mm for PN 6.3 pipe)

C = Hazen-Williams constant = 145 – 150 for Poly/PVC pipe (145 used)

$$\mathbf{H_L = ((3.35 \times 10^6\ Q) \div (d^{2.63}\ x\ C))^{1.852}}$$

Substituting in values = $((3.35 \text{ x } 10^6 \text{ x } 2) \div (55.2^{2.63} \text{ x } 145))^{1.852}$

Head Loss per 100m = $(6.7 \text{ x } 10^6 \div 5.4 \text{ x} 10^6)^{1.852}$

= 1.42 m per 100m

The 573m PN6.3 section of the pipeline therefore contributes a head loss of

= 1.42m x 5.73

∴ PN6.3 section of pipeline = 8.15 m head loss

As each grade of pipe exhibits a different internal diameter it is again necessary to repeat the process for the PN 9, PN 12 and PN 16 sections of the pipeline.

Results are tabulated in Table 3.

Using this method the Effective (Net) head available at turbine = Static head – hydraulic losses

∴ Net Head = 160 – 29.7 = 130.3m @ 2 l/s flow

This result is within 4.5% of the value calculated using the manufacturers web based tool. This confirms the integrity of both methods. These values are also compared with the actual measured results in section 5.1 of this thesis.

Grade	Quantity(m)	Head Loss(m)	Pipe IDmm
PN6	573	8.15m	55.2
PN9	250	3.73m	54.8
PN12	200	4.18m	51.0
PN16	250	5.22m	51.0
Pipe joins	14 at 0.5m loss each	7.00m	
Gate valves	2 gate valves at 0.7m loss	1.40m	
Total	**1273m**	**29.68 m head loss**	

Table 3 Calculation of head loss using Hazen and Williams method

From the design tool results summarized in table 2 (Iplex, 2007) it can be seen that a flow velocity through the pipeline will be slightly less than 1m/s depending on the grade of pipe used in that section.

Finally the discharge pipe (tailrace) must be large enough to ensure that no backpressure is apparent and all of the discharge water is immediately removed from the turbine. As mentioned earlier submerging a Pelton wheel will seriously impair turbine operation. Accordingly a short length of 80mm diameter PVC drainage pipe was installed to ensure trouble free discharge of water to a nearby creek.

3.10 Turbine/generator

It was decided that the construction of a turbine and alternator was beyond the scope of this project and a commercially supplied unit would allow greater focus on engineering and academic aspects of the project.

Clearly, the optimal type of turbine will be strongly influenced by the resources available at the site. Fortunately the Totara Valley site offered a wide range of viable Micro-Hydro sites and it was decided that a high head low flow site offered a technical challenge and the most economic solution for this project.

In view of the 160m head and low flow rates the most efficient turbine type for our high head, low flow site is the Pelton Wheel (*Wilson, 1962)*. The Pelton wheel offers good efficiency at high heads and features relatively small flow rates. It is therefore a good choice for this application. At the scale of the Totara Valley turbine the Pelton wheel exhibits a relatively high speed of rotation that offers a good match to the generator, which also requires high rotational speeds for good efficiency.

After researching several overseas-made Micro-Hydro turbines it was decided to purchase a locally manufactured unit supplied and engineered by Eco-Innovations. There were several reasons for choosing this particular turbine. Firstly the turbine is of Pelton Wheel design and is competitively priced at $1,200 including a good supply of spare parts. Furthermore spare parts (Pelton buckets, bearings and alternator parts) are locally available at reasonable cost. Specifications and images of the unit are included in appendix 7.

The generator is constructed from a surplus "Fisher & Paykel" smart drive washing machine motor. Therefore, offering a recycled product that complemented the environmental objectives of the project well.

Eco-Innovations also offered considerable technical documentation with their unit. The design of the generator is very flexible and allowed for optimization of the generator and turbine configuration for maximum efficiency. Nozzle sizes were also readily changeable offering further optimization of the turbine efficiency. The unit also offered considerable scope for modification and experimentation.

Finally the turbine utilizes standard agricultural irrigation fittings, which together with the pipeline are available locally under the "IPLEX®" brand name. Massey University has good contacts with "IPLEX®" for purchasing and technical support and consequently they were chosen to supply the pipeline for this project. This product is widely available throughout New Zealand and Australia, facilitating straightforward duplication of similar Micro-Hydro systems throughout the region. The use of locally manufactured components supports the policy of MUCER to support local Renewable energy (RE) manufacturers where possible and contribute towards the development of the New Zealand RE industry.

Figure 16 Turbine undergoing initial testing

3.11 Inverter

Four different inverter options were explored. Three of these units were maximum power point tracking (MPPT) units that offered the advantage of high efficiency while accepting wide range of input voltages on the DC side. Two of the inverters required a battery to stabilize the DC supply.

A summary of the features of each unit is presented in table 4.

Model	Output Power	MPPT	DC input voltage	Battery required	cost	Comments
SMA "Windy Boy" 1100-LV	1100W	Yes	21 - 60 volts	optional	$ 3,999.00	versatile,proven,smart
Fronius IG2000	1800W	Yes	150 - 450 volts	No	$ 4,499.00	smart, desgned for solar PV
Trace SW3048	3000W	No	24 or 48 volts	Yes	$ 5,295.00	not certified, older generation technology
Energy Recyclers	2000W	yes	36 - 57 Volts	Yes	$ 5,900.00	expandable

Table 4 Summary of Inverters surveyed

The four units considered included the “Windy Boy” manufactured by SMA technology in Germany. These units are popular overseas and well proven. Furthermore they are certified for connection to the grid in New Zealand. They offer excellent versatility and have the ability to be used as a stand-alone power system with the addition of a “Sunny Island” controller. They can also be remotely monitored, a definite advantage for this project. Had an inverter not been donated to the project this is the unit that would have been recommended.

The Fronius IG2000 is also manufactured in Germany. Whilst a modern design and well proven outside New Zealand, these units were difficult to obtain and local support was not available at this time. Furthermore the required DC input voltage requirements were higher than expected, presenting a safety risk. For these reasons this unit was considered unsuitable for this project.

The widely used Trace Engineering (now Xantrex) SW3048 was also considered. These units are popular and are familiar to most renewable energy installers. They also offer good local support. However they are expensive, utilize early generation technology and offer considerably greater output capacity than what is required for this project. These units are not certified in New Zealand for grid connection and were therefore considered unsuitable.

Finally the Energy Recyclers “2kW Master” was recommended by IRL, one of the project sponsors. These units are manufactured in Auckland and offer some unique features. In particular they can be programmed to maintain a fixed voltage on the DC supply, therefore offering a steady load to the hydro turbine. They are also capable of upgrading to 6kW output with the addition of “slave” modules. These units are certified for connection to the New Zealand grid and offer local technical support.

Importantly one of the project sponsors (IRL) has considerable experience with these units and offered to donate a fully programmed unit to the project.

For these reasons the “Energy Recyclers” unit was selected for this project.

This unit is primarily intended for the efficient discharge testing of high capacity deep cycle batteries used in remote telecommunications and utility sites. As an alternative to wasteful dummy loads the unit synchronizes with the mains supply and returns energy to the grid.

Technical details of the Energy Recyclers unit are included in appendix 6.

Figure 17 Energy Recyclers Inverter mounted in a protective cabinet

3.12 DC Voltage Regulation

The Energy Recyclers inverter requires a continuous and stable 50V DC supply free of voltage spikes and under voltage abnormalities. The unit can be set to discharge a battery to a specified DC voltage and will automatically adjust the DC load to maintain this voltage.

The inverter was programmed to maintain the battery voltage at 55.2V, which is the recommended float voltage for batteries of this type. In this mode of operation the unit allows grid synchronisation and exporting of electricity into the electricity network.

However in the event of an inverter failure the batteries would not be maintained at a steady float voltage and would eventually become overcharged leading to premature battery failure. Furthermore excessive voltages on the DC side presented a risk of destroying the DC circuitry within the inverter. The turbine manufacturers also warned that without a constant load the turbine could over speed and create a safety hazard.

As the site is unattended an additional and reliable method of turbine load regulation was therefore necessary.

This is the purpose of the battery and Trace C40 regulator. The battery provides smoothing of the turbine output and also has sufficient storage to operate the system for several minutes without turbine support. The Trace C40 diversion regulator diverts any excess energy into a

2kW dummy load (heater) should the battery voltage rise above 58V thereby protecting the turbine, inverter and battery. Full specifications of the Trace C-40 are included in appendix 8.

Figure 18 Trace Engineering C40 load diversion charge controller

Several additional components are included. The alarm output is provided to indicate when the 2kW load is dissipating energy.

If the battery voltage exceeds 58V the C40 diverts the excess turbine output power into the 2kW dummy load. This voltage also appears across the coil of RL1 and closes the contacts connected to the “alarm output” terminals. The intention is to connect these terminals to a future telemetry system to allow remote fault reporting back to the Massey University campus.

A Voltmeter and Ammeter have been installed to allow visitors to quickly confirm correct operation of the system. An appropriate fuse was installed on the battery lead to protect system components. This fuse is rated at 40 Amperes, sufficient to comfortably carry the charge and discharge currents present on the battery wiring but still small enough to protect system components and wiring in the event of a short circuit. Finally the batteries were selected to match the requirements of the Turbine and the Inverter. In summary they must be nominally 50 volts and be capable of being charged and discharged. Storage capacity is not critical and the battery size was selected to provide adequate storage capacity balanced against cost and ease of transportation. (Lead acid batteries are very heavy).

The final circuit schematic diagram of the system is depicted in Figure 19.

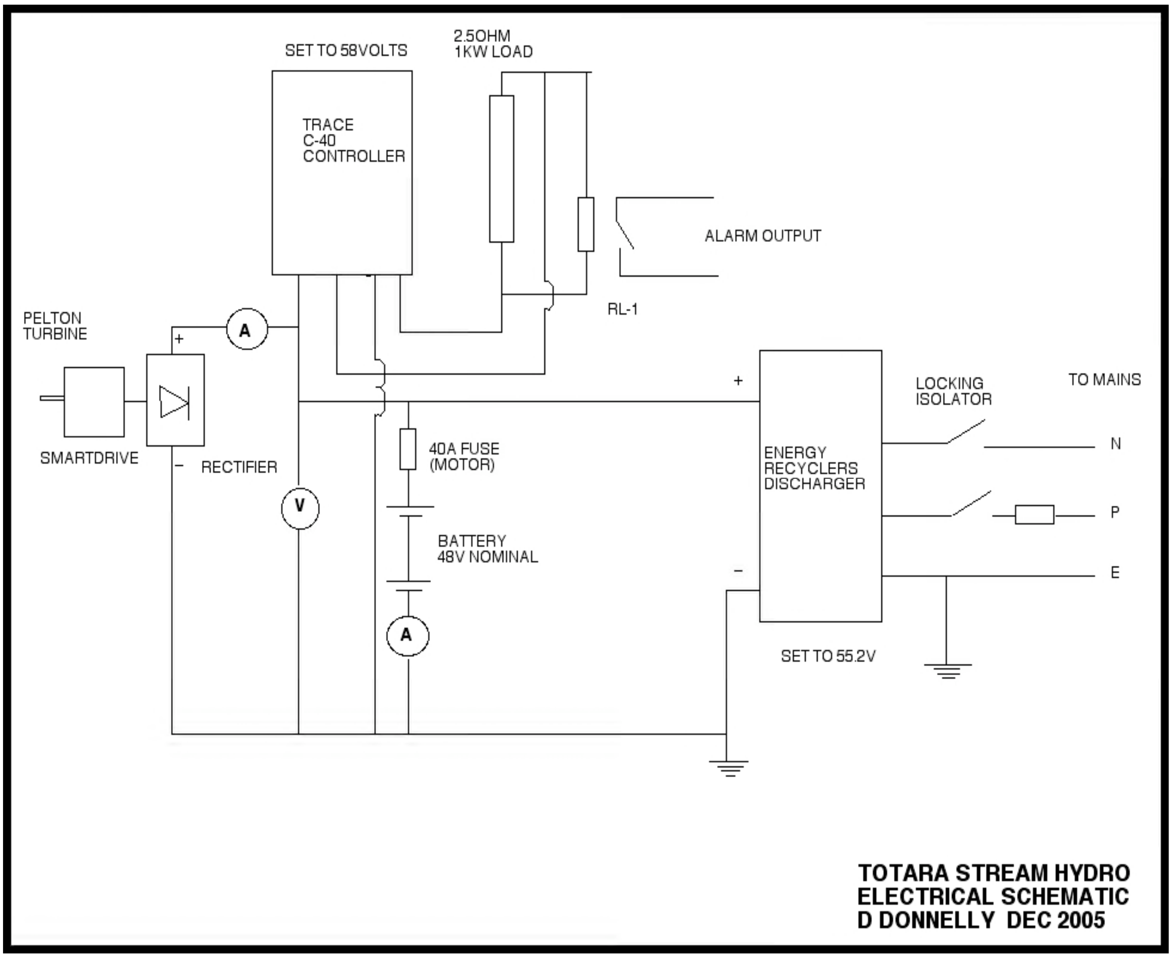


Figure 19 Electrical Schematic Diagram of installed system

Figure 20 System components including pipe fittings(left), dump load(front) Battery links (black objects front right) and batteries (top of picture).

3.13 Calculation of flow velocity

Flow velocity within the intake pipe can be quantified from first principles. Calculations are based on a 2 litres/second flow rate and the dimensions of the "Polyflex" pipe selected for this project.

Flow (Q) = Pipe internal cross sectional area (A) × velocity of fluid (V)

$\therefore$ V = Q ÷ A   (PN9 grade pipe internal diameter = 55mm, Q = 2 litres/sec)

$\therefore$ $V = Q/\pi r^2 = 0.002 \div 3.14 \times (0.0275)^2$

Therefore V = 0.84 m/s through the PN-9 grade pipe

As summarised in table 2 the water velocity will be slightly different through the other grades of pipe due to their variations in internal diameters.

3.14 Calculation of output power

From the discussion in section 2 of this report the expected output from a hydro turbine can be calculated from the following formula

$Pw = Q \times h \times g \times \eta$ (1) (Boyle, 2004)

Q represents the quantity of water passing through the turbine in kg per second. As discussed in section 2.2 the available water supply is constrained by the conditions of the Resource Consent to a 2 litres per second flow rate so this parameter has been predetermined. Therefore Q = 2 litres/sec = 2 kg/sec

h is the effective head available at the turbine, from the results presented in table 2 we can expect a net operating head of 131.6 m (h).

g is the gravitational acceleration constant and quantifies the acceleration of falling objects on earth due to the force of gravity. $g = 9.8\ ms^{-2}$

η is the symbol for efficiency and in this case it denotes the mechanical efficiency of the turbine. It is important to appreciate that there are two energy conversions taking place within the turbine assembly. Firstly the kinetic energy of the water hitting the pelton buckets is converted into mechanical energy to rotate the turbine. Secondly the generator, which is attached to the turbine shaft, converts this mechanical energy into electricity. Both of these conversions result in a loss of some energy. The turbine manufacturer “Eco-Innovations” claims a mechanical efficiency (η) of 70% for their turbine.

Substituting into (1) above

$Pw = 2 \times 131 \times 9.8 \times 0.7$

Therefore Output Power (mechanical) = 1784W at the output shaft of the turbine

The manufacturer also advises a 70% conversion efficiency can be anticipated for the generator. We can therefore expect, Pw(electrical) = 1784W x 0.7 (η) = 1249W of electrical output

This is realistic and is in line with the results obtained during testing. Further discussion comparing this calculation with the experimental results is presented in section 5.1 of this report.

3.15 Approximation of water velocity at jet

In addition it is possible to evaluate from first principles the expected jet velocity and jet diameter when the jet sizes are small relative to the pipe diameter.

As the water "falls" it looses its potential energy and gains kinetic energy. If this conversion is 100% efficient, all of the potential energy is converted into kinetic energy. In reality friction between the water and the pipe walls will reduce the conversion efficiency to less than 100%.

From the discussion above the potential energy of the water at the intake site is

Q x g x h.

From physics theory when a mass (water) is moving its kinetic energy is

$^{1}/_{2}\ MV^{2}$. (2)

If the system did not incur losses then all of the potential energy is converted into kinetic energy and potential and kinetic energy will equate when the conversion is complete

$^{1}/_{2}\ MV^{2} = Mgh$ (Q equates to M)

$V^2 = 2gh$ rearranging for V (3)

$V = \sqrt{(2gh)}$ (4) (Boyle, 2004)

Substituting into this formula the values from the Totara Valley intake system we get

$V = \sqrt{(2 \times 9.8 \times 130)}$ (The net head is used to include frictional losses)

V_{jet} = 50 m/s ..velocity of water expelled from the jet

3.16 Determination of jet size

Now that the velocity through the jet and the flow rate is known it is possible to calculate the required jet area. If water flows through a jet of area A at a velocity V_{jet} then the flow rate (Q) equates to A x $V_{jet.}$

In this example we know Q and V_{jet} , therefore A can be found by rearranging the formula.

By rearranging $Q = A \times V_{jet}$

therefore $A = Q/V_{jet}$ (5)

Substituting in project values $A = 0.002m^3s^{-1}/50ms^2 = 0.00004m^2$

As the jet is circular $A = \pi r^2$

Therefore the jet orifice radius $r = \sqrt{(A/\pi)}$

Substituting in the project values

$r = \sqrt{(0.00004/\pi)}$

Therefore the jet radius r = 0.0035m = 3.5mm

The jet orifice diameter *D = 2r = 7mm diameter*

After initial testing it was found that the Pelton runner vibrated excessively with a single jet. The manufacturer subsequently recommended that we upgrade the system by installing two jets to improve the turbine balance. To maintain a total 2 litres per second flow through two jets, each jet was required to discharge 1 litre per second.

The jet orifice is circular and from the formula above it is apparent that the orifice area (and therefore flow rate) is proportional to the square root of the radius of the jet orifice. Therefore to half the flow rate the diameter of the jet will need to be decreased by a factor of $\sqrt{0.5} = 0.707$.

Each jet orifice should therefore be 7mm x 0.707 = 5mm diameter

To verify this is true it is possible to work back

Flow rate = $\pi r^2 \times V_{jet}$ = $3.1415 \times 0.0025^2 \times 50$ ($\pi = 3.1416$, $r = d/2$)

= 0.001 m^3/sec - which equates to a 1 litre per second flow through each jet orifice.

We therefore started by drilling two new jets with 5mm diameter holes to obtain 1 litre per second flow through each jet. Table 5 (2004, Eco-innovations) is presented for comparison. Although the table does not extend to 130m head it does demonstrate that the calculated jet size is realistic and is around 5mm.

Jet sizing table – flows in L/s

Head	Jets Sizing (mm)																			
m	3	3.2	3.4	3.6	3.8	4	4.2	4.4	4.6	4.8	5	5.2	5.4	5.6	5.8	6	7	8	9	10
5	0.07	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.18	0.19	0.21	0.23	0.24	0.26	0.28	0.38	0.50	0.63	0.78
10	0.10	0.11	0.13	0.14	0.16	0.18	0.19	0.21	0.23	0.25	0.28	0.30	0.32	0.35	0.37	0.40	0.54	0.70	0.89	1.10
15	0.12	0.14	0.16	0.17	0.19	0.22	0.24	0.26	0.29	0.31	0.34	0.36	0.39	0.42	0.45	0.49	0.66	0.86	1.09	1.35
20	0.14	0.16	0.18	0.20	0.22	0.25	0.27	0.30	0.33	0.36	0.39	0.42	0.45	0.49	0.52	0.56	0.76	1.00	1.26	1.56
25	0.16	0.18	0.20	0.23	0.25	0.28	0.31	0.34	0.37	0.40	0.43	0.47	0.51	0.55	0.59	0.63	0.85	1.11	1.41	1.74
30	0.17	0.20	0.22	0.25	0.28	0.30	0.34	0.37	0.40	0.44	0.48	0.52	0.56	0.60	0.64	0.69	0.93	1.22	1.54	1.91
35	0.19	0.21	0.24	0.27	0.30	0.33	0.36	0.40	0.44	0.47	0.51	0.56	0.60	0.65	0.69	0.74	1.01	1.32	1.67	2.06
40	0.20	0.23	0.25	0.29	0.32	0.35	0.39	0.43	0.47	0.51	0.55	0.60	0.64	0.69	0.74	0.79	1.08	1.41	1.78	2.20
45	0.21	0.24	0.27	0.30	0.34	0.37	0.41	0.45	0.49	0.54	0.58	0.63	0.68	0.73	0.79	0.84	1.14	1.49	1.89	2.33
50	0.22	0.25	0.28	0.32	0.36	0.39	0.43	0.48	0.52	0.57	0.62	0.67	0.72	0.77	0.83	0.89	1.21	1.57	1.99	2.46
55	0.23	0.26	0.30	0.33	0.37	0.41	0.46	0.50	0.55	0.59	0.65	0.70	0.75	0.81	0.87	0.93	1.26	1.65	2.09	2.58
60	0.24	0.28	0.31	0.35	0.39	0.43	0.48	0.52	0.57	0.62	0.67	0.73	0.79	0.85	0.91	0.97	1.32	1.72	2.18	2.70
65	0.25	0.29	0.32	0.36	0.41	0.45	0.49	0.54	0.59	0.65	0.70	0.76	0.82	0.88	0.94	1.01	1.37	1.80	2.27	2.81
70	0.26	0.30	0.34	0.38	0.42	0.47	0.51	0.56	0.62	0.67	0.73	0.79	0.85	0.91	0.98	1.05	1.43	1.86	2.36	2.91
75	0.27	0.31	0.35	0.39	0.44	0.48	0.53	0.58	0.64	0.69	0.75	0.81	0.88	0.94	1.01	1.08	1.48	1.93	2.44	3.01
80	0.28	0.32	0.36	0.40	0.45	0.50	0.55	0.60	0.66	0.72	0.78	0.84	0.91	0.98	1.05	1.12	1.52	1.99	2.52	3.11
85	0.29	0.33	0.37	0.42	0.46	0.51	0.57	0.62	0.68	0.74	0.80	0.87	0.94	1.01	1.08	1.15	1.57	2.05	2.60	3.21
90	0.30	0.34	0.38	0.43	0.48	0.53	0.58	0.64	0.70	0.76	0.83	0.89	0.96	1.04	1.11	1.19	1.62	2.11	2.67	3.30
95	0.31	0.35	0.39	0.44	0.49	0.54	0.60	0.66	0.72	0.78	0.85	0.92	0.99	1.06	1.14	1.22	1.66	2.17	2.75	3.39
100	0.31	0.36	0.40	0.45	0.50	0.56	0.61	0.67	0.74	0.80	0.87	0.94	1.01	1.09	1.17	1.25	1.70	2.23	2.82	3.48

Table 5 Recommended jet (nozzle) sizes (courtesy Eco-innovations)

3.17 Rotational speed of turbine runner

Finally one can also calculate the rotational velocity of the turbine under ideal conditions. As discussed in Wilson (1962) when the Pelton turbine runner is moving at half of the jet velocity it is theoretically extracting the maximum kinetic energy from the moving water.

The manufacturer's standard Pelton rotor is installed on the Totara valley turbine. This rotor exhibits a "running" diameter of 240mm giving an overall circumference of

$$C = 2\pi R = 2.00 \times 3.14 \times 0.120 = 0.75 \text{ m} \qquad (6)$$

Assuming the rotor is turning at half of the water velocity, the buckets will be moving at 25 m/s. As the buckets move 0.75m during each rotation they will rotate at…

$$RPS = 25.0 ms^{-1} \div 0.75m = 33.3 \text{ revolutions per second}$$

This equates to 33.3rps x 60sec = 2000 RPM

From the data supplied by the turbine manufacturer in Table 6 this is somewhat higher than the maximum recommended 1800 RPM. The high speed is a consequence of operating a turbine designed for a 120m nominal head at a greater 130m net head featured at the Totara Valley site. Consequently the manufacturer supplied a balanced rotor better suited to the higher rotational speed. A safety cage was also installed on the turbine as a safety precaution. A larger diameter Pelton runner is available should reduction of the running speed prove necessary in the future.

Table of ideal Pelton/Turgo running speeds

Head	Pelton or Turgo Runner Diameter (mm)																	
m	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500
5	1702	1135	851	681	567	486	426	378	340	309	284	262	243	227	213	200	189	179	170
10	2407	1605	1204	963	802	688	602	535	481	438	401	370	344	321	301	283	267	253	241
15	2948	1966	1474	1179	983	842	737	655	590	536	491	454	421	393	369	347	328	310	295
20	3404	2270	1702	1362	1135	973	851	757	681	619	567	524	486	454	426	401	378	358	340
25	3806	2538	1903	1523	1269	1088	952	846	761	692	634	586	544	508	476	448	423	401	381
30	4170	2780	2085	1668	1390	1191	1042	927	834	758	695	641	596	556	521	491	463	439	417
35	4504	3002	2252	1801	1501	1287	1126	1001	901	819	751	693	643	600	563	530	500	474	450
40	4815	3210	2407	1926	1605	1376	1204	1070	963	875	802	741	688	642	602	566	535	507	481
45	5107	3404	2553	2043	1702	1459	1277	1135	1021	928	851	786	730	681	638	601	567	538	511
50	5383	3589	2691	2153	1794	1538	1346	1196	1077	979	897	828	769	718	673	633	598	567	538
55	5646	3764	2823	2258	1882	1613	1411	1255	1129	1026	941	869	807	753	706	664	627	594	565
60	5897	3931	2948	2359	1966	1685	1474	1310	1179	1072	983	907	842	786	737	694	655	621	590
65	6138	4092	3069	2455	2046	1754	1534	1364	1228	1116	1023	944	877	818	767	722	682	646	614
70	6369	4246	3185	2548	2123	1820	1592	1415	1274	1158	1062	980	910	849	796	749	708	670	637
75	6593	4395	3296	2637	2198	1884	1648	1465	1319	1199	1099	1014	942	879	824	776	733	694	659
80	6809	4539	3404	2724	2270	1945	1702	1513	1362	1238	1135	1048	973	908	851	801	757	717	681
85	7019	4679	3509	2807	2340	2005	1755	1560	1404	1276	1170	1080	1003	936	877	826	780	739	702
90	7222	4815	3611	2889	2407	2063	1806	1605	1444	1313	1204	1111	1032	963	903	850	802	760	722
95	7420	4947	3710	2968	2473	2120	1855	1649	1484	1349	1237	1142	1060	989	927	873	824	781	742
100	7613	5075	3806	3045	2538	2175	1903	1692	1523	1384	1269	1171	1088	1015	952	896	846	801	761
105	7801	5200	3900	3120	2600	2229	1950	1733	1560	1418	1300	1200	1114	1040	975	918	867	821	780
110	7984	5323	3992	3194	2661	2281	1996	1774	1597	1452	1331	1228	1141	1065	998	939	887	840	798
115	8164	5442	4082	3265	2721	2332	2041	1814	1633	1484	1361	1256	1166	1088	1020	960	907	859	816
120	8339	5560	4170	3336	2780	2383	2085	1853	1668	1516	1390	1283	1191	1112	1042	981	927	878	834

Smart Drive RPM Not Recommended | Marginal | OK | Preferred Smart Drive RPM

The above table is shaded to show the preferred working speeds of a Smart Drive PMG. This preferred running RPM is where the speed of the unit is below 1200 rpm. Above this speed the Smart Drive rotor will need balancing. It generally should not be run above 1800 rpm, at this speed you run the risk of rotor failure, due to higher stresses on the components at these speeds

Table 6 Recommended turbine speed (courtesy Eco-innovations)

However this is still a marginal running speed, particularly for continuous operation. The project objective is to obtain a reliable 1 kW output on a continuous basis. This necessitated reducing the flow rate and therefore the rotational speed of the runner to within acceptable limits. The degree of loading the alternator places on the turbine also impacts significantly on the final rotational velocity. The degree of turbine loading can be adjusted by means of shims, which alter the interaction between the magnetized stator and the armature. This adjustment can be used to control the final rotational speed.

This concludes the design and modeling facet of the project. It can be seen from the previous discussion that the important system parameters have now been quantified. In section 5 these values are compared with the experimental results and variances are discussed.

4.0 Legal and administrative obligations and barriers

4.1 Resource consent process

Subsequent to the site survey arrangements were made to meet a planner at the "Horizons Regional Council" to learn about the likely costs and resource consent requirements the project may encounter.

The following points arose:

1) three consents will be needed to implement this project; a building consent if it is decided to construct small weir. This was not considered a major problem providing engineering and geological reports are obtained. Because of the considerable time and cost involved it was later decided to design an alternative intake system that would not require construction of a Dam;
2) a Diversion consent for taking ("abstraction") of water from Totara stream;
3) a Discharge permit for discharging of water into Totara stream. In view of the fact that this is a minor diversion of a waterway this should be all that is necessary to continue with an application.

Under the provisions of the District plan if the diversion/discharge is less than the 50 cubic metres per day for domestic use it is deemed to be a permitted activity.

However this project will require the diversion of 172 cubic metres per day and is therefore deemed to be a discretionary activity. Should the council consider it to have minimal impact on the environment then it will issue a non-notified consent. The cost will be approximately $800.00 if all goes well.

If the council feels there may be objections from neighbours, Fish and Game Association, or local Iwi then the consent will need to be publicly notified. Should this happen and there are no objections the cost will be approximately $3,000.

Should there be objections and there is a need for hearings the cost is likely to balloon to greater than $10,000 if the application is to progress further.

After several discussions the council proposed an application be submitted for the project together with approval letters from affected neighbours, the Department of Conservation and Fish and Game New Zealand. Should no objections be received the project will be accepted as a non-notified discretionary activity. These approval letters are included with other resource consent documentation in appendix one of this report.

In view of the small percentage of the total stream flow being diverted, the environmental effects will be minimal. As there are several existing waterfalls on the stream the project offers no additional effects should migrating fish species be identified in future, an issue that the council initially expressed concerns about.

If litigation or further "consultancy" becomes necessary to obtain a resource consent then the financial feasibility of the project is in question.

4.2 Interconnection regulations

The project was also required to obtain approval to connect to the local electrical distribution company's grid. At the time of connection there was no legislation governing the connection of distributed generators. Connection of distributed generation projects was solely at the discretion of the local network distribution company. Most distribution companies were not supportive of small generators or alternatively had no policy on the connection of distributed generation projects to their networks.

Fortunately one of the project sponsors was the distribution company Mainpower, (Christchurch). Mainpower conducted these negotiations with Scanpower (the local distribution company) on the MUCER's behalf. To their credit Scanpower were happy for the project to connect to their network providing certain safety precautions were observed. Specifically the wiring had to comply with the NZ/AS3000 standard, a lockable isolation switch was required on the system and the inverter was required to meet specific technical standards. These requirements are now encompassed in the standard AS4777 (Grid connection of energy systems via inverters). In particular this standard requires that the inverter is shutdown immediately if it cannot detect existing mains voltage on the grid. This is referred to as anti-islanding and ensures that the inverter does not liven up lines that have been isolated by the lines company for maintenance. The requirements requested by Scanpower are entirely reasonable and ensure the safety of Scanpower staff working on the lines connected to Totara Valley.

Whilst the connection of this project was achieved without difficulty some discussion of recent changes in the legislation regarding distributed generation is warranted.

As discussed in the literature review this process is now legislated and distributed generators will now find distribution companies willing to deal with them. It is interesting to review how the industry has got to the position it is in today. Examination of the Commerce Commission website (http://www.comcom.govt.nz/IndustryRegulation/Electricity/ElectricityLinesBusinesses) reveals an interesting history of intervention by the Commission in the electricity industry, particularly in regard to overcharging by lines companies. In March 2005 the Commerce Commission successfully defended a joint appeal to the Court of Appeal by four lines companies. This case allowed the Commission to set “thresholds” which effectively limit the charges lines companies can charge consumers and foster a more competitive electricity distribution market.

In late 2005 the Commerce Commission announced its intention to “take control” of “Unison Networks” and “Vector” to remedy a number of anti competitive practices. Finally in January 2006 things became more adversarial as the Commission announced its intention to declare control over “Transpower” the Government owned electricity transmission operator.

In response to the anti competitive behaviour, Commerce Commission intervention and lobbying from a number of groups including The Association of Independent Generators the Ministry of Economic Development’s approach altered from “hands off” to a more intervention based regime. Part of their response included a discussion paper on the role of distributed generators and the rules governing their connection to Electricity Networks. From the preceding discussion the reader may conclude that to restore credibility to the industry Government intervention had become necessary at this time. This intervention process endured over several years and concluded with the passing of several pieces of legislation including the Electricity Governance (“connection of distributed generation”) Regulations in September 2007. Projects seeking connection after this time are now subject to these regulations.

These regulations clearly set out the responsibilities of the Lines Companies and how they deal with distributed generators. They divide Distributed generation projects into small <10kW and large projects. These are treated differently as the potential effects of larger projects on Network stability present considerably greater risk. The processes and maximum fees payable by the distributed generator are enshrined in the legislation and provide a degree of certainty for small generators. Future owners of similar systems to Totara Valley are likely to encounter considerably less difficulty in connecting to their distribution company compared to what existed before these regulations became law.

In conclusion the author supports the view proposed by Ackermann, “the regulatory aspects might decisively influence the development of distributed power generation” (Ackermann et all, 2000). This statement referred to the European electricity market and is equally applicable to the development of distributed generation in New Zealand.

Over the next few years the reality of this assertion in a New Zealand context will be tested.

Finally it is to their credit that the two distribution companies involved in the Totara Valley project negotiations have been innovative in their approach to distributed generation projects and are extremely supportive of this project.

4.3 Feed-in Tariffs

A further consideration for the distributed generator is the payment they receive from the electricity retailer for each kWh they export to the grid. This is referred to as the feed-in tariff. In spite of the apparently beneficial aspects of the new interconnection regulations discussed in the previous section, New Zealand has no regulations regarding what feed-in tariffs electricity retailers pay to distributed generators for exported electricity.

This is a critical aspect of energy regulation that has not been addressed in the New Zealand market. Contrast this with Germany where guaranteed feed-in tariffs have underpinned remarkable growth in the German renewable energy industry (Federal Ministry for Economics & Technology, 2007). This has not only substantially improved Germany's proportion of total energy from renewable resources. It has also provided new jobs for people working within the renewable energy sector. Germany has become the largest solar PV market in the world, this has been attributed to the policies outlined above. (Atkinson, 2007). Remarkably this has been achieved despite possessing only mediocre solar resources (Atkinson, 2007). In fact German legislation has proved so successful that feed-in tariffs are now regulated in 16 European states and several other countries including Canada, Israel and more recently South Australia (SA Government, 2007).

The South Australian state regulations require retailers to pay renewable based distributed generators $0.44 per kWh for 20 years on systems up to 10kVa. (SA Government, 2007) This equates to three times the present retail electricity price and is intended to stimulate the distributed generation industry and contribute towards a reduction of greenhouse gas emissions in the State. Similar legislation is expected to become law in the Australian Capital Territory and the Northern Territory (Australia) in early 2008.

Several New Zealand retailers were contacted and asked what rates they pay distributed generators for exported electricity. Regrettably no retailers contacted were prepared to respond to questions on feed-in tariffs. The author contacted the Energy Efficiency and Conservation Authority, (EECA) to establish the current market situation. EECA were only aware of one retailer paying the full retail price to some distributed generators (Meridian Energy) and most paid considerably less (Mayhew, 2008).

Clearly this is not an equitable market for distributed generators and New Zealand policy contrasts poorly with that of many other nations.

In view of the expected contributions distributed generation can make to the Government's Greenhouse gas reduction targets and the convincing arguments in support of distributed generation submitted to Government by the Commissioner for the Environment, the Government's position on this issue is disappointing.

Furthermore the Government has a conflict of interest in this issue. On one hand it is careful to ensure state owned electricity generators and their retail businesses remain profitable. On the other hand it needs to materially support all efforts to abate greenhouse gas emissions and develop a more equitable electricity market.

Distributed generators should be paid a fair price for the electricity they generate that reflects the benefits they provide network operators and other consumers. Distributed generation systems provide network operators and larger suppliers with additional network capacity to cover peak load demands. Distributed generators also provide voltage support on remote lines and contribute to the availability of "green electricity" on the network. In consideration of these factors distributed generators offer electricity that is of greater value than base load generation and they therefore should be paid a premium price for their electricity.

5.0 Results

5.1 Technical Results

Leakage problems within the pipe work were experienced as a consequence of the high pressures present in the turbine end of the intake pipeline. Several leaks required repairing and on one occasion the pressure gauge blew completely off its fitting. Fortunately careful replacement of plastic components with brass fittings has rectified these problems.

During construction a pressure gauge was permanently installed into the end of the pipe at the turbine end. This enables observation of static and operating pressure within the pipe and also calculation of the operating head. Upon commissioning these measurements were observed and recorded.

With the turbine gate valve closed the static pressure was observed as 1580 kPa (full scale deflection). As the pressure gradient on a vertical pipe is 9.81 kPa per metre of head the calculated static head from the pressure gauge reading is 161m (1580kPa/9.81). With the valve open and a flow rate of 2.0 l/s the operating pressure was observed as 1280kpa. This equates to an effective head of 130.6 m. This is a very satisfactory outcome that validates the theoretical analysis outlined in section 3.8.

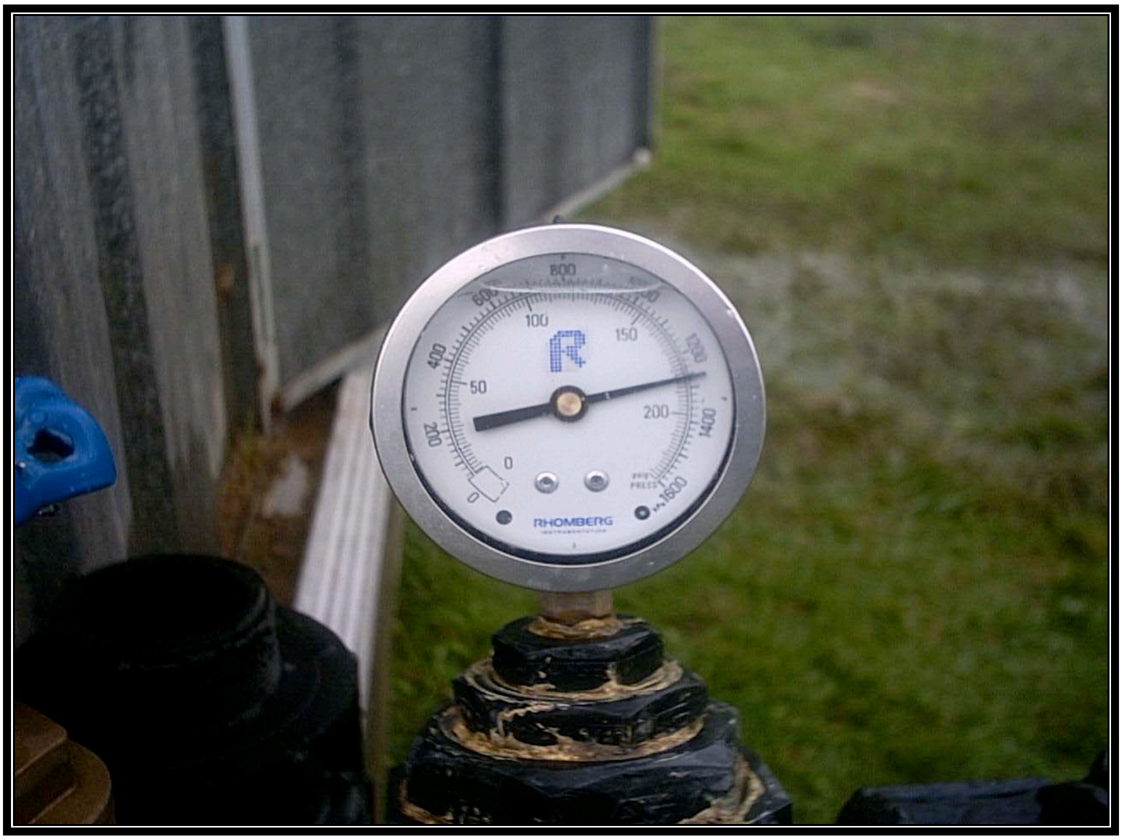


Figure 21 Observed operating pressure @ 2 L/sec flow measured at the turbine

It also validates the assumptions made regarding the flow resistance of the joiners and gate valves. The small error is acceptable and can be attributed to the following factors:

1) accuracy of altitude measurements and changes in barometric pressure during the time altitude measurements were taken;

2) bends and “dips” in the pipe that contribute to increased frictional losses;

3) manufacturing tolerances of components and instruments used;

4) an 8 L bucket and stopwatch were used to measure flow. This method offers limited accuracy;

5) there is some doubt regarding the frictional losses incurred through each joint, the manufacturer states they are “Negligible” (Iplex, 2007). However other texts consulted suggested allowing 0.5m head loss for each joint (TAFE, 2000). Accordingly a 0.5m allowance was made for each joint and the gate valves. These suggestions proved to be credible.

Upon completion the turbine generated a useful electrical output of 57Volts at 23A (1311Watts) that was successfully fed into the grid. Flow at this output was measured at 2.3 litres per second at an electrical output of 1311W.

Substituting into equation (1) section 2.0

The actual potential energy available W = 2.3(Q) x 9.8(g) x 129(h) = 2907W

The overall efficiency of the system (mechanical & electrical) is therefore

$$\eta = 1311/2907 \times 100 = 45\%$$

From the manufacturer's data we had expected an overall efficiency of 49%. This is derived from $\eta = 0.49$ being the product of the mechanical and electrical efficiency.

$\eta_{total} = \eta_{mechanical} \times \eta_{electrical}$ which equates to 0.7 x 0.7 = 0.49

Some further work optimizing jet sizes and runner speed can be expected to yield a few more percentage points in efficiency.

After some testing the flow was reduced until 1 kW output was achieved to enhance long-term reliability and comply with our maximum consented 2 L/sec flow rate.

Operation of the Trace C40 diversion controller and the associated dump load was also verified.

5.2 Operational Results

We left the unit running and Massey staff returned approximately a week later to check progress. Regrettably the inverter had switched itself off and all of the energy was being dissipated in the dump load. We later discovered that the inverter had a software problem and it had to be sent back to IRL for repair.

A further concern arose when the turbine manufacturer cautioned that we might encounter some erosion of the plastic buckets used in the manufacture of the Pelton Wheel. In view of their minimal cost we considered this a reasonable risk. Furthermore observation of this wear would provide useful data on the future choice of materials for manufacturing these components.

After this initial problem we left the turbine running, to learn if the silt in the water supply was indeed causing any erosion problems on the Pelton buckets. It was also an opportunity to assess the long-term reliability of the turbine and the protection system (dump load and regulator).

Four months later turbine had to be temporarily shut down due to a bearing failure on the turbine runner. Discussion with the manufacturer in May 2007 revealed that this is a known problem and the likely cause of failure was water ingress into the bearing assembly. An improved sealing kit is now available from the manufacturer.

Contrary to our earlier concern, after 4 months operation no wear was evident on the plastic Pelton buckets from particles suspended in the intake water.

Although most large commercial hydro turbines are relatively maintenance free this project demonstrated that smaller micro turbines require regular maintenance and this should be factored into the financial modeling. As turbines are typically operating continuously components need to be sturdy and able to withstand the constant mechanical stress of operation. Bearings and electrical components should be well sealed against the ingress of water. Furthermore higher speed designs such as Pelton and Turgo turbines should be well balanced to minimize fatigue from vibration.

Finally we had safety concerns regarding the pressure of the water at the base of the pipeline. At 1600kPa care would be needed to avoid potentially hazardous water jets. In practice we found that when the jet nozzles were removed and the gate valve was fully opened frictional losses in the pipeline quickly reduced the pressure and flow rate to easily manageable levels. After a few seconds it was even possible to change fittings without shutting off the intake gate valve.

5.3 Environmental results

As a renewable based project it is appropriate to review the environmental effects it imposes on its surroundings. An environmental impact report was completed as part of the resource consent application and is included in appendix 1. It is not proposed to duplicate this discussion within this report. However the project is expected to offset the emission of greenhouse gases and this aspect was not presented in the original consent application. It is therefore appropriate to discuss this aspect of the project.

The quantity of emissions avoided has been calculated in Table 8 using a model on the New Zealand Business Council for Sustainable Development (nzbcsd, 2008) Web site (Available at www.nzbcsd.org.nz/climatechange). The results from the “nzbcsd model” predict that for each kWh of electricity generated during 2008 in New Zealand, 150 grams of greenhouse gases are emitted.

The equation used in the Table 8 spreadsheet is based on this figure and the methodology is summarized below.

Assuming the Totara Valley turbine is generating a constant 1kW this equates to 24kWh per day. Allowing for maintenance and breakdowns it has been assumed that the turbine will be operational for 50 weeks every year, this equates to 8,400 kWh per year or 84,000 kWh over a 10 year project life.

Therefore total emissions avoided = 84,000 x 0.150kg/kWh = 12,600 kg over the 10 year project life

To check the integrity of this model it is necessary to refer to official Government statistics. The Ministry of Economic Development publishes quarterly figures for total electricity production and greenhouse gas emissions. This statistical information is available at the Ministry for Economic Development (MED, 2008) website www.med.gov.nz. Fortunately the emissions statistics are available by sector and the statistics for thermal electricity generation are available separately.

The figures for June 2005 show that CO_2 emissions as a consequence of electricity generation were 6041 x 10^3 tonnes (MED, 2008). Figures for other greenhouse gases were less than 500 tonnes.

Total electricity generation was 42,000 GWh (MED, 2008). Interestingly 55% of total generation was attributable to hydro-based resources.

Therefore on average the production of electricity within New Zealand releases

6041×10^6 kg ÷ 42×10^9 kWh = 144 grams per kWh

This validates the results obtained using the “nzbcsd model” and endorses the formula used in the spreadsheet model presented in section 5.4. It also confirms that if the turbine performs as expected the project can be expected to avoid 1260 kg of CO_2 emissions each year.

5.4 Economic analysis of project

A spreadsheet based financial model was developed to compare various scenarios of this project and also allow the evaluation of similar projects. A description and instructions on using the model are included in appendix 10. A working copy of the spreadsheet model is included on the CD attached to this publication. The model is limited to scenarios where generated power is exported to the grid or substituted for previously imported energy. The model includes two sections, an “Input sheet” that captures all of the capital costs and provides an evaluation of the total capital cost involved.

In addition to this part "B" of the "Input Sheet" captures ongoing costs and project specific data for a life cycle cost analysis. When data entry is complete users can select the "Results" tab to examine a summary of financial data for their project including the following parameters:

1. the net present value of the project calculated using the selected discount rate over a 10 year project life;
2. the value of electricity generated each year, adjusted for inflation, electricity price escalation and the selected discount rate;
3. the average cost per unit of the electricity generated in cents/kWh, adjusted for inflation, electricity price escalation and the selected discount rate;
4. the avoided Greenhouse Gas emissions based on the carbon intensity of the existing imported supply and the annual electricity output of the project;
5. finally the Internal Rate of Return can be calculated by clicking once on the IRR button (This macro button is visible on the screenshots available in appendix 10).

A presentation of a discounted cash flow analysis (DCF) for the project is also available for the users consideration. It is suggested the user examines the DCF presentation before clicking on the button to calculate the Internal Rate of Return (IRR). By definition the IRR is the discount rate that yields an NPV of zero and when the IRR button is clicked the discount rate will be automatically adjusted until this criteria is achieved.

The financial viability of the Totara valley hydro development project was initially examined using the actual costs incurred. However, this approach does not truly represent the expected costs to construct an identical system as many of the materials and labour for this project were donated. Accordingly a second analysis is presented which encompasses all of the costs expected on a project of this size.

The following items were donated to this project and a zero value has been attributed to them in the first analysis:

1. Shed;
2. Inverter;
3. Control and monitoring Panel;
4. Connection charges to the "Scanpower" network;
5. Labour for design, construction and management of the project.

The initial analysis is presented in tables 7 & 8.

To summarise, the actual capital cost of the project was $9,759 and the project yielded a respectable Internal rate of return (IRR) of 18.4%.

The financial assumptions made for this analysis are:

1) a discount rate of 4% was initially used for this analysis as this equates to the after tax earnings on funds deposited in a typical savings account;

2) electricity price is assumed to be 23.4c/kWh. This the rate charged by Meridian Energy in the Wairarapa Region during May 2007 (Meridian Energy, 2007). Output from the turbine will ultimately offset the quantity of imported electricity, therefore the sale price is assumed to be the same;

3) an annual inflation rate of 2.5% is assumed. This figure is taken from the Reserve Bank CPI index 2006-2007 (NZ Government, 2007);

4) it is assumed electricity will increase in price an average of 10% each year (including inflation). Although this may appear somewhat excessive retail prices increased 13% between May 2006 and May 2007 (Meridian Energy, 2007) and further increases are expected due to natural gas supply shortages and the introduction of a carbon tax;

5) a maintenance allowance of $650 is allocated each year. This is made up of scheduled maintenance trips at $400 pa and one unscheduled maintenance visit each year ($250);

6) avoided Greenhouse gas emissions are based on an emissions calculator published by the New Zealand Council for Sustainable Development (NZBCSD, 2008) Figures have been further checked against the "Energy and Transformation Industries Gas Emissions" annual report published by the Ministry of Economic Development (MED, 2008).

A considerable 52% of the project budget was spent on materials for constructing the pipeline. In retrospect this project required a relatively lengthy pipeline and similar projects are likely to show a better rate of return given shorter distances to transport water. The other significant cost was the resource consent application fee, which equated to 16% of the final project cost. Contrary to expectations the cost of the turbine was not the main contributor to the total project cost.

Micro-hydro cost model

Input Sheet

Part A - Capital cost Analysis

Enter costs in Yellow cells below
Calculated values are displayed in green cells

Material costs

Item	Grade	Metres	cost/m		Cost
Turbine cost					$1,200.00
Shed, Shelter					$0.00
Total cost Pipe & fittings (Itemised in gold cells below)		Enter itemised costs in Yellow cells below, total pipe and battery costs will appear in appropriate green cell		Total pipe costs are here >	$5,080.60
Breakdown of Pipe costs	PN6	600	$2.48	$1,488.00	
	PN9	250	$3.17	$792.50	
	PN12	200	$3.36	$672.00	
	PN16	250	$6.86	$1,715.00	
	Fittings(cost each)	15	$27.54	$413.10	
	Other	0	$0.00	$0.00	
		Number	Cost each		
Batteries (If required)		8	$75.00	Total battery costs are here >	$600.00
Inverter					$0.00
Voltage Regulator (If not supplied with turbine)					$250.00
Control panel, meters monitoring equipment					$0.00
Electrical fuses, wiring and fittings					$300.00
Diversion load					$200.00
Pipe and other materials for tailrace construction					$120.00
Other Materials					$0.00

Administration & Consent Costs

Resource consent charges	$1,589.00
Connection charges	$0.00

Labour costs

Item	Hours	Rate/hour		Cost
Electrician, grid connection	6	$ 70.00	< Enter labour costs here	$420.00
Non specialist labour	80	$ -		$0.00
Consultancy Fees				$0.00
Other Works				$0.00

Total capital cost **$9,759.60**

Part B - Enter values for cashflow analysis

Item	Value	Unit
Enter total kWh generated per annum	8400	Kwh
Enter electricity sale price cents/kWh	23.40	cents
Enter annual inflation rate %	2.5	%
Enter annual electricity price increase (% in addition to inflation rate)	10.0	%
Enter discount rate % (required investment return)	18.4	%
Annual maintenance costs	$400.00	
Annual ongoing Resource consent fees	$200.00	
Unscheduled maintenance allowance	$250.00	
Carbon intensity of existing grid supply in kg CO_2/kWh generated	0.15	Kg/kWh

Table 7 Capital cost analysis of actual project

Table 8 depicts the long term financial analysis of the project. As mentioned earlier IRR has been calculated at 18.4%, a respectable return on the initial investment and certainly better than investing the funds in a bank account, although the risk is somewhat higher.

At 17 cents/kWh the cost of generation is considerably higher than that achieved by competing large generators. However it is still less than the retail electricity price and therefore offers a net benefit to the owner.

Micro-hydro cost model

Summary Results

Capital cost	$ 9,759.60	
Net present value of system	$ 0.00	
Total kWh output over project life	84,000	kWh
Average unit cost of electricity generated	$ 0.17	cents/kWh
Greenhouse gas emissions avoided over project life	12,600	kg
Internal rate of return of project	18.40	%

Value of electricity generated each year (in installation year dollar value)

Installation Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
$ 1,965.60	$ 1,826.17	$ 1,696.64	$ 1,576.29	$ 1,464.48	$ 1,360.60	$ 1,264.09	$ 1,174.43	$ 1,091.12	$ 1,013.72

Discounted cashflow analysis

	Installation Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Income										
Value of electricity generated	$ 1,965.60	$ 2,162.16	$ 2,378.38	$ 2,616.21	$ 2,877.83	$ 3,165.62	$ 3,482.18	$ 3,830.40	$ 4,213.44	$ 4,634.78
Discount factor	0.00	1.18	1.40	1.66	1.97	2.33	2.75	3.26	3.86	4.57
Present value per kWh generated	$ 0.23	$ 0.26	$ 0.28	$ 0.31	$ 0.34	$ 0.38	$ 0.41	$ 0.46	$ 0.50	$ 0.55
Present value of electricity	$ 1,965.60	$ 1,826.17	$ 1,696.64	$ 1,576.29	$ 1,464.48	$ 1,360.60	$ 1,264.09	$ 1,174.43	$ 1,091.12	$ 1,013.72
Expenses										
Initial capital investment	$ 9,759.60									
maintenace	$ -	$ 400.00	$ 410.00	$ 420.25	$ 430.76	$ 441.53	$ 452.56	$ 463.88	$ 475.47	$ 487.36
resource consent fees	$ -	$ 200.00	$ 220.00	$ 242.00	$ 266.20	$ 292.82	$ 322.10	$ 354.31	$ 389.74	$ 428.72
unscheduled maintenance	$ 250.00	$ 250.00	$ 275.00	$ 302.50	$ 332.75	$ 366.03	$ 402.63	$ 442.89	$ 487.18	$ 535.90
total expenses	$ 10,009.60	$ 850.00	$ 905.00	$ 964.75	$ 1,029.71	$ 1,100.37	$ 1,177.29	$ 1,261.08	$ 1,352.40	$ 1,451.98
Discount factor	0.00	1.18	1.40	1.66	1.97	2.33	2.75	3.26	3.86	4.57
Present value of expenses	$ 10,009.60	$ 717.92	$ 645.59	$ 581.27	$ 524.00	$ 472.95	$ 427.38	$ 386.66	$ 350.22	$ 317.58
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Annual present value of project	$ (8,044.00)	$ 1,108.26	$ 1,051.05	$ 995.02	$ 940.48	$ 887.66	$ 836.71	$ 787.77	$ 740.90	$ 696.15
Net present value of system	$ 0.00	Over 10 year project life								

Table 8 Life cycle financial analysis of actual Totara Valley Project

However, a major cost that was not incurred in this project was labour. A commercially based project would show a considerably lower rate of return when real labour costs are accounted for. Accordingly a second analysis was completed that includes all items at their real cost. In summary the physical construction of the project took 4 people 2 days to complete. With additional finishing work this equates to around 80 man-hours of voluntary work. In addition to this considerable time was spent preparing the consent application, dealing with stakeholders, conducting preliminary research, raising finance and obtaining project materials. Furthermore the lines company is now expected to charge a prescribed fee to connect the system to their grid. The maximum fee allowed under Schedule 4 of the new Distributed generation regulations is $200 (this is quoted on most company web sites). This figure has therefore been included in this analysis.

Finally the shed, the inverter, and the control panel were donated to this project. It is therefore appropriate for a second analysis to include these costs to fairly represent a similar project constructed on a commercial basis. The result is shown in table 9.

Micro-hydro cost model
Input Sheet

Part A - Capital cost Analysis

Enter costs in Yellow cells below
Calculated values are displayed in green cells

Item	Grade	Metres / Number / Hours	cost/m / Cost each / Rate/hour	Calculated	Cost
Material costs					
Turbine cost					$1,200.00
Shed, Shelter					$355.00
Total cost Pipe & fittings (Itemised in gold cells below)				Total pipe costs are here >	$5,080.60
		Enter itemised costs in Yellow cells below, total pipe and battery costs will appear in appropriate green cell			
	Grade	Metres	cost/m		
Breakdown of Pipe costs	PN6	600	$2.48	$1,488.00	
	PN9	250	$3.17	$792.50	
	PN12	200	$3.36	$672.00	
	PN16	250	$6.86	$1,715.00	
	Fittings(cost each)	15	$27.54	$413.10	
	Other	0	$0.00	$0.00	
		Number	Cost each		
Batteries (If required)		8	$75.00	Total battery costs are here >	$600.00
Inverter					$6,000.00
Voltage Regulator (If not supplied with turbine)					$250.00
Control panel, meters monitoring equipment					$200.00
Electrical fuses, wiring and fittings					$300.00
Diversion load					$200.00
Pipe and other materials for tailrace construction					$120.00
Other Materials					$0.00
Administration & Consent Costs					
Resource consent charges					$1,589.00
Connection charges					$200.00
Labour costs		Hours	Rate/hour		
Electrician, grid connection		6	$ 70.00	< Enter labour costs here	$420.00
Non specialist labour		80	$ 20.00		$1,600.00
Consultancy Fees					$0.00
Other Works					$0.00
Total capital cost					**$18,114.60**

Part B - Enter values for cashflow analysis

Item	Value	Unit
Enter total kWh generated per annum	8400	Kwh
Enter electricity sale price cents/kWh	23.40	cents
Enter annual inflation rate %	2.5	%
Enter annual electricity price increase (% in addition to inflation rate)	10.0	%
Enter discount rate % (required investment return)	2.9	%
Annual maintenance costs	$400.00	
Annual ongoing Resource consent fees	$200.00	
Unscheduled maintenance allowance	$250.00	
Carbon intensity of existing grid supply in kg CO_2/kWh generated	0.15	Kg/kWh

Table 9 Capital cost analysis including true market costs of materials and labour

As depicted in table 10 the impact of including all costs in the project is substantial. The capital cost of the project almost doubles and this deteriorates the long-term financial outcome. The price of generated electricity rises above the retail price to 32 cents per kWh, this implies that the project is not financially viable as it is less expensive to purchase electricity from the grid.

Furthermore the IRR has reduced to 2.9 %, consequently a better return on the project investment funds can be found in a term deposit account. On this basis the project is not financially viable.

Micro-hydro cost model

Summary Results

Capital cost	$ 18,114.60
Net present value of system	$ (0.00)

Value of electricity generated each year (in installation year dollar value)

Installation Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
$ 1,965.60	$ 2,101.13	$ 2,246.02	$ 2,400.89	$ 2,566.43	$ 2,743.40	$ 2,932.57	$ 3,134.78	$ 3,350.93	$ 3,581.99

Total kWh output over project life	84,000	kWh
Average unit cost of electricity generated	$ 0.32	cents/kWh
Greenhouse gas emissions avoided over project life	12,600	kg
Internal rate of return of project	2.90	%

Discounted cashflow analysis

	Installation Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Income										
Value of electricity generated	$ 1,965.60	$ 2,162.16	$ 2,378.38	$ 2,616.21	$ 2,877.83	$ 3,165.62	$ 3,482.18	$ 3,830.40	$ 4,213.44	$ 4,634.78
Discount factor	0.00	1.03	1.06	1.09	1.12	1.15	1.19	1.22	1.26	1.29
Present value per kWh generated	$ 0.23	$ 0.26	$ 0.28	$ 0.31	$ 0.34	$ 0.38	$ 0.41	$ 0.46	$ 0.50	$ 0.55
Present value of electricity	$ 1,965.60	$ 2,101.13	$ 2,246.02	$ 2,400.89	$ 2,566.43	$ 2,743.40	$ 2,932.57	$ 3,134.78	$ 3,350.93	$ 3,581.99
Expenses										
Initial capital investment	$ 18,114.60									
maintenace	$ -	$ 400.00	$ 410.00	$ 420.25	$ 430.76	$ 441.53	$ 452.56	$ 463.88	$ 475.47	$ 487.36
resource consent fees	$ -	$ 200.00	$ 220.00	$ 242.00	$ 266.20	$ 292.82	$ 322.10	$ 354.31	$ 389.74	$ 428.72
unscheduled maintenance	$ 250.00	$ 250.00	$ 275.00	$ 302.50	$ 332.75	$ 366.03	$ 402.63	$ 442.89	$ 487.18	$ 535.90
total expenses	$ 18,364.60	$ 850.00	$ 905.00	$ 964.75	$ 1,029.71	$ 1,100.37	$ 1,177.29	$ 1,261.08	$ 1,352.40	$ 1,451.98
Discount factor	0.00	1.03	1.06	1.09	1.12	1.15	1.19	1.22	1.26	1.29
Present value of expenses	$ 18,364.60	$ 826.01	$ 854.64	$ 885.35	$ 918.29	$ 953.61	$ 991.47	$ 1,032.06	$ 1,075.56	$ 1,122.16
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Annual present value of project	$ (16,399.00)	$ 1,275.13	$ 1,391.38	$ 1,515.54	$ 1,648.15	$ 1,789.79	$ 1,941.09	$ 2,102.72	$ 2,275.37	$ 2,459.83
Net present value of system	$ (0.00)	Over 10 year project life								

Table 10 Life cycle cost analysis, true market value of materials and labour

However, it is worthwhile considering what can be done to remedy the situation. In this project the intake pipeline contributes towards a substantial portion of the total cost, therefore reducing the head to a more manageable 120m would remove the need to purchase expensive PN16 grade pipe. The intake could be sited closer to the turbine and a small increase in flow rate would be required to maintain output. The shorter pipeline would also reduce installation costs and the number of fittings required. During the discussion on inverters it was stated that the SMA “Windy Boy ” inverter would probably have been integrated into the system if the present unit were not donated. This implies a lower cost inverter and also the batteries and associated wiring can be eliminated, as this inverter does not require batteries. For safety reasons the voltage regulator and diversion load would be retained.

The result of these changes is depicted in Table 11 and 12. In summary the IRR increases to 9.5% a more acceptable figure and certainly better than interest rates offered by most financial institutions. The average cost of generated electricity reduces to 24 cents per unit, which is marginally more expensive than the retail electricity supplied from the grid. However the locally produced electricity avoids around 1260 kg of greenhouse gas emissions each year.

Further improvements can be achieved through fair pricing of resource consents. The present charges are not consistent across local authorities and the fact that additional ongoing fees are payable to the local authority further deteriorates the viability of these projects. Furthermore at the time of granting a resource consent the council concerned was unable to reveal exactly what these ongoing fees are likely to be.

Micro-hydro cost model

Input Sheet

Part A - Capital cost Analysis

Enter costs in Yellow cells below

Calculated values are displayed in green cells

Material costs

Turbine cost					$1,200.00
Shed, Shelter					$355.00
Total cost Pipe & fittings (Itemised in gold cells below)				Total pipe costs are here >	$3,255.44
		Enter itemised costs in Yellow cells below, total pipe and battery costs will appear in appropriate green cell			
	Grade	Metres	cost/m		
Breakdown of Pipe costs	PN6	600	$2.48	$1,488.00	
	PN9	250	$3.17	$792.50	
	PN12	200	$3.36	$672.00	
	PN16	0	$6.86	$0.00	
	Fittings(cost each)	11	$27.54	$302.94	
	Other	0	$0.00	$0.00	
		Number	Cost each		
Batteries (If required)		0	$0.00	Total battery costs are here >	$0.00
Inverter					$3,999.00
Voltage Regulator (If not supplied with turbine)					$250.00
Control panel, meters monitoring equipment					$200.00
Electrical fuses, wiring and fittings					$300.00
Diversion load					$200.00
Pipe and other materials for tailrace construction					$120.00
Other Materials					$0.00

Administration & Consent Costs

Resource consent charges	$1,589.00
Connection charges	$200.00

Labour costs

	Hours	Rate/hour		
Electrician, grid connection	6	$ 70.00	< Enter labour costs here	$420.00
Non specialist labour	70	$ 20.00		$1,400.00
Consultancy Fees				$0.00
Other Works				$0.00

Total capital cost $13,488.44

Part B - Enter values for cashflow analysis

Enter total kWh generated per annum	8400	Kwh
Enter electricity sale price cents/kWh	23.40	cents
Enter annual inflation rate %	2.5	%
Enter annual electricity price increase (% in addition to inflation rate)	10.0	%
Enter discount rate % (required investment return)	9.5	%
Annual maintenance costs	$400.00	
Annual ongoing Resource consent fees	$200.00	
Unscheduled maintenance allowance	$250.00	
Carbon intensity of existing grid supply in kg CO_2/kWh generated	0.15	Kg/kWh

Table 11 Capital cost analysis after changes are implemented

On this basis the project would be a marginal proposition and would benefit from further cost savings or other incentives to make it an attractive proposition. The introduction of a carbon tax credit or Renewable Energy Certificates (REC's) would be a sufficient incentive to stimulate renewable based projects of this nature.

Micro-hydro cost model

Summary Results

Capital cost	$ 13,488.44	
Net present value of system	$ (0.00)	

Value of electricity generated each year (in installation year dollar value)

Installation Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
$ 1,965.60	$ 1,974.63	$ 1,983.70	$ 1,992.81	$ 2,001.96	$ 2,011.15	$ 2,020.39	$ 2,029.67	$ 2,038.99	$ 2,048.36

Total kWh output over project life	84,000	kWh
Average unit cost of electricity generated	$ 0.24	cents/kWh
Greenhouse gas emissions avoided over project life	12,600	kg
Internal rate of return of project	9.50	%

Discounted cashflow analysis

	Installation Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Income										
Value of electricity generated	$ 1,965.60	$ 2,162.16	$ 2,378.38	$ 2,616.21	$ 2,877.83	$ 3,165.62	$ 3,482.18	$ 3,830.40	$ 4,213.44	$ 4,634.78
Discount factor	0.00	1.09	1.20	1.31	1.44	1.57	1.72	1.89	2.07	2.26
Present value per kWh generated	$ 0.23	$ 0.26	$ 0.28	$ 0.31	$ 0.34	$ 0.38	$ 0.41	$ 0.46	$ 0.50	$ 0.55
Present value of electricity	$ 1,965.60	$ 1,974.63	$ 1,983.70	$ 1,992.81	$ 2,001.96	$ 2,011.15	$ 2,020.39	$ 2,029.67	$ 2,038.99	$ 2,048.36
Expenses										
Initial capital investment	$ 13,488.44									
maintenace	$ -	$ 400.00	$ 410.00	$ 420.25	$ 430.76	$ 441.53	$ 452.56	$ 463.88	$ 475.47	$ 487.36
resource consent fees	$ -	$ 200.00	$ 220.00	$ 242.00	$ 266.20	$ 292.82	$ 322.10	$ 354.31	$ 389.74	$ 428.72
unscheduled maintenance	$ 250.00	$ 250.00	$ 275.00	$ 302.50	$ 332.75	$ 366.03	$ 402.63	$ 442.89	$ 487.18	$ 535.90
total expenses	$ 13,738.44	$ 850.00	$ 905.00	$ 964.75	$ 1,029.71	$ 1,100.37	$ 1,177.29	$ 1,261.08	$ 1,352.40	$ 1,451.98
Discount factor	0.00	1.09	1.20	1.31	1.44	1.57	1.72	1.89	2.07	2.26
Present value of expenses	$ 13,738.44	$ 776.28	$ 754.82	$ 734.86	$ 716.31	$ 699.08	$ 683.08	$ 668.23	$ 654.46	$ 641.71
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Annual present value of project	$ (11,772.84)	$ 1,198.35	$ 1,228.88	$ 1,257.94	$ 1,285.65	$ 1,312.08	$ 1,337.32	$ 1,361.44	$ 1,384.53	$ 1,406.65
Net present value of system	$ (0.00)	Over 10 year project life								

Table 12 Long term financial performance after changes are implemented

6.0 Conclusions

This project demonstrated that the technical design and construction of a modern micro-hydro system is an achievable undertaking. It can be readily duplicated at many sites with appropriate design considerations. It also established that some aspects of the project consumed considerably more resources than expected and therefore impacted significantly on the financial viability of this type of project.

This study shows that the critical cost drivers in a project of this nature are:

1) the length of the pipe run between the intake site and the turbine;

2) the quantity and head of water available at the turbine site;

3) the costs associated with obtaining and retaining a resource consent;

4) electricity pricing if grid connected.

To minimize pipeline costs the length of the intake pipe should be as short as possible. In addition to the cost of the pipeline one must account for the cost and logistics associated with its installation. For similar projects it is recommended that the pipeline is kept to the absolute minimum length possible.

Generally a high head site will be less expensive to develop compared to a low head site of comparable output. This is because the lower head site will require much larger components and a larger diameter pipeline to achieve a comparable electrical output.

We found that the cost of the PN16 grade pipe was considerable and contributed 34% to the total pipeline cost in spite of only comprised 19% of the total pipeline length. In retrospect when using polyethylene pipeline it is more economic to limit a system of this type to a maximum120m head. This permits the use of less expensive PN6 – PN12 grade pipe with only minimal loss of output.

Furthermore the additional wear on components as a consequence of the 160m head has not been quantified. However it is expected that this factor will add additional maintenance costs to the system.

A project budgeted on a commercial basis as presented in table 11 and 12 is only marginally viable and whilst it provides a reasonable rate of return on the initial investment the cost of generated electricity is similar to that purchased from the grid.

It is expected that many of these schemes will be installed by motivated landowners who will be willing to provide their own time and labour. In return they will gain the personal satisfaction and security of generating their own electricity, reduce their energy costs and gain a degree of control over their energy supply.

It is anticipated other altruistic motivations such as reducing personal CO_2 emissions will also motivate potential system builders.

The financial outcome highlights the need for fair incentives for renewable based distributed generation and shows that small concessions can go a long way towards making these systems truly viable.

These incentives do not need to be large or unfair to competing technologies and only need to offer the distributed generator a fair return on the electricity they export to the grid.

For example the benefits of proposed carbon credits should be directly payable to the owners of distributed generation systems to sell and therefore contribute towards the financial viability of the system.

Whilst it can be shown that larger systems can be expected to generate electricity at a lower cost per kWh, this does not detract from the appeal of small hydro systems. It is evident from recent publicity that gaining planning approval for large hydro projects in New Zealand is problematical. This indicates that there are probably no further large-scale hydro sites available in New Zealand that can be realistically developed. However there are still many sites that could be realistically developed with much smaller scale projects. These systems can be installed with minimal environmental disruption and are much less visible than large hydro or wind turbines.

This project has demonstrated that it is not necessary to build a dam to implement a successful system. The absence of an obstruction in a stream significantly reduces the environmental impact of the project. As a consequence the legal costs and community opposition to establish a project are also mitigated.

This is particularly true if projects are locally owned and revenues are returned to the local economy. The economic and social benefits of profits remaining within the local economy are further benefits of this approach.

This project demonstrated that because the scheme was not visible to surrounding properties and did not impact on the neighbours' enjoyment of their property they were happy to grant their support to the project.

A further advantage of distributed generation is that power can be generated where it is needed, thereby reducing the transmission losses encountered when generation is only available at a few sites within a network. This is particularly important in rural communities such as Totara Valley that are located at the end of long distribution lines. In this situation even small schemes offer some voltage stabilization benefits even though they cannot supply the full community load.

Finally a large network of small generators offers consumers a more secure supply as the failure of a single small supplier is of little consequence to the rest of the network. Contrast this with the failure of a large power station that would typically cause a major blackout.

The cost of the resource consent for this project was considerable and much of this cost is not reflected in the financial analysis. Considerable time on this project was spent complying with the administrative and local authority requirements necessary for the granting of resource consents. The environmental benefits of renewable distributed generation are considerable and well documented, therefore the owners of these systems should not be penalized with unfair resource consent fees. Of particular concern was the apparently random way consent charges were calculated and the fact that additional ongoing charges will be payable to the local authority concerned. As mentioned earlier the council concerned was unable to tell us exactly what these ongoing fees are likely to be.

These factors introduce considerable uncertainty and unwelcome costs into renewable projects and are therefore a significant disincentive to adopt renewable technologies.

Policy changes are necessary to ensure unreasonable local authority charges do not undermine the worthwhile contribution these small schemes can make to the economy, energy infrastructure and greenhouse gas abatement efforts. Similar legislation to that recently targeted at lines companies would appear to offer a good solution to the problem of excessive local authority consent charges.

Commercial sale of the electricity to a retailer was not a prime objective of this project. However most prospective owners will need a clear indication of what price they are likely to receive for electricity sold to their local retailer and what costs are likely to be incurred for connection to the grid.

The new Electricity Governance Regulations have gone some way towards making distributed generation a more secure investment.

However the absence of a legislated feed-in tariff has hindered any serious investment in renewable based distributed generation. Legislation is required in the New Zealand market to provide distributed generators a fair and secure return for the electricity they export to the grid.

The benefits of distributed generation have been highlighted in this study and have been clearly presented to the Government by the Commissioner for the Environment. Regrettably this dysfunctional aspect of the New Zealand electricity market has not received the attention that it merits.

This policy vacuum introduces further uncertainty for all small distributed-generators intending to grid connect.

Under present policy conditions the majority of small renewable system owners are likely to limit their activities to small non-consented stand-alone systems. New Zealand has excellent renewable resources, however the absence of clear and fair institutional policies within the energy market have restrained participants from taking full advantage of the opportunities these resources offer.

7.0 Future Directions

This project offers the foundation for several new energy research projects in the Totara Valley.

Firstly a project sponsor suggested the testing of induction motors and other types of turbine for suitability in this application as a good research project. The successful implementation of an induction motor can potentially provide low cost grid synchronization without the expense of an inverter.

The valley encompasses several viable micro-hydro sites and the possibility of establishing a low head site was investigated during early surveying for this project. Several of these sites were found to be feasible for future development.

Some further research would be beneficial towards optimizing the efficiency and operation of this project. For example only minimal work was completed optimizing jet sizes on this turbine. Due to the requirement to meet other project objectives a detailed study of the effects of changing the jet sizes and the number of jets was not conducted.

There are also two unresolved issues relating to the reliability of the inverter software and the durability of the bearings supporting the turbine. These issues will require further investigation.

Finally, Totara valley is approximately a one-hour drive from the Massey campus and consequently detailed monitoring and control of the system is difficult. The design and installation of a remote monitoring system would greatly enhance the accessibility of all of the Totara Valley projects to students and staff. The provision of raw system data on campus would form the basis for future study and system improvements. It would also provide researchers with up to the minute operational parameters, fault reporting and the possibly of remote control of system operation. The projects also offer considerable scope for the design of software for monitoring and controlling system operation. Finally the availability of real-time data on campus would create the possibility to present this data on a web page thereby promoting MUCER activities to a wider audience.

8.0 References

Ackermann, T. Andersson, G. Soder, L (2000) *Electricity Utility Deregulation and Restructuring*, , Proceedings DRPT 2000 International Conference, London, IEEE

AMPA. (2004) *Australian Pump Technical Handbook*, 4th Ed, pp 38 – 43, Sydney NSW, Pump Industry Australia Inc

Atkinson, V. (2007) *Move To Clean Energy Must Be Started Soon*, 16-May-2007, *NZ Herald*

Beetles, L. <leeb@scanpower.co.nz> (2008, Feb 29). Re: distributed generation. [Personal email]

Boyle, G. (2004) *Renewable Energy, Power For A Sustainable Future*, 2nd Ed, pp 147-194, Oxford, Oxford University Press

Cleaver, R. (2006) Build A Hydro Power Plant, *The Shed*, Aug – Sep 2006, pp 30-38, Auckland, Cadenza publishing

Cole, J. (2005). *Joe's pipe calc's* spreadsheet no longer available for download, Joe's hydro web site available at http://home.carolina.rr.com/unclejoe/

Commerce Commission, *Electricity Lines Businesses*, accessed 07-02-08 from http://www.comcom.govt.nz/IndustryRegulation/Electricity/ElectricityLinesBusinesses

Cunningham, P. Woofenden, I. (2006) Intro to Hydropower, *Homepower Magazine*, (105), Feb-Mar 2006, Ashland OR, USA, Home Power inc

Energy Recyclers Ltd, (2005) *Battery Discharger Specification Sheet*, Energy Recyclers Ltd, Accessed 12-03-07. www.energyRecyclers.com

Federal Ministry for the Environment and Economics, (2007) *German Renewable Energy*, Bonn, Germany. Accessed 20-06-07. www.german-renewable-energy.com/en

Horizons Regional Council, (2005) *Land And Water Regional Plan*, pp 67 – 93, 141-144, Palmerston North, Horizons Regional Council

IPLEX® Ltd Australia, (2001) *Flow Resistance Chart For Water At 20^{0}C*, Sydney NSW, Iplex Industries Ltd

IPLEX® Ltd Australia, (2007) *Iplex Design Tool*, Sydney NSW, Iplex Industries Ltd, Accessed 25–05-07 www.iplex.com.au

IPLEX® Ltd New Zealand, (2006) *Fact Sheet Polyplex Pipelines*, Palmerston North, Iplex Industries Ltd, Accessed 27-5-07. www.iplex.co.nz

Lawley, M. (2004) *Pelton Turbine Installation Manual*, Eco-Innovations, Accessed 14-May-07, from www.ecoinn.co.nz

Lawley, M. (2004) *Pelton Smartdrive Water Turbines*, Accessed 26-May-07, from www.ecoinn.co.nz

Lawley, M. (2004) *Smartdrive interconnection Manual*, Eco-Innovations, purchased from www.ecoinn.co.nz

Lloyd, B. Lowe, D. Wilson, L. (2000), *Renewable Energy in Remote Australian Communities , (A market Survey)*, ACRE, Rockingham, Murdoch University

Mayhew, J. <j.mayhew@eeca.gov.nz> (2008, March 05). Re: feed in tariffs. [Personal email]

Meridian Energy (2007) *Pricing + Plans*, Accessed 5-May-07, from www.meridanenergy.co.nz

Ministry of Economic Development, (June 2005) *New Zealand Energy Greenhouse Gas Emissions 1990 – 2004 , Energy and Transformation Industries*, pp 23 – 25 Wellington, MED. Available for download at www.med.govt.nz

Ministry of Economic Development, (2008) *Electricity Generation Summary*, Accessed 25-03-08 from www.med.govt.nz

Ministry for the Environment, (1991) *Resource Management Act*, Wellington, New Zealand Government

New Zealand Business Council for Sustainable Development, (2008) *Emissions Calculator*, Accessed 25-03-08 from www.nzbcsd.org.nz/climatechange/

Reserve Bank of New Zealand (2007) *CPI index 2006-2007*, Wellington, New Zealand Government, 2007)

Scanpower, Lee Beetles, personal communication, 29 February 2008.

South Australian Government (2008) *First feed-in laws pass Parliament*, press release 14-2-08, Mike Rann Premier SA. Accessed 5-3-08 from www.premier.sa.gov.au/news

Staff, Renewable Energy Centre, (2003) *RET 201 Resource Book*, pp 06-29, Brisbane, Brisbane Institute of TAFE.

Staff, (1993) *Rural And Remote Area Power Supplies For Australia*, pp 23 – 27, Canberra, Department of Primary Industries and Energy

Staff, (2003) *Trace C40 Installation Manual*, Arlington WA, Xantrex Corporation, supplied with controller.

Staff, (2004) *Micro-Hydropower Systems: A Buyers Guide*, Natural Resources Canada, Ottawa, Government of Canada. Available at http://builditsolar.com/Projects/Hydro/hydro.htm

Staff, (2003) *Trace PS4825 Owners Manual*, Arlington WA, USA Xantrex Corporation, Accessed 17/2/07 from www.xantrex.com

Standards Australia, (2007) *Grid connected Inverters AS4777.* Available for purchase at (www.standards.com.au)

Standards New Zealand, (2007) *New Zealand Wiring Rules NZ/AS3000.* Available for purchase at (www.standards.co.nz)

Turner, L. (2005) Micro Hydro Buyers Guide, *Renew*, (92), Dec 2005, 50 –53. Alternative Technology Association, Melbourne, Australia.

Wilson, P. N. (1962) *Water Turbines Simply Explained*, London, Gilbert Gilkes and Gordon Ltd.

9.0 List of Appendices

Appendix 1 Resource Consent Correspondence

This appendix contains the key documents exchanged during the resource consent process.
Included documents include

1. **The initial application letter together with the Assessment of Environmental Effects document.**
2. **Letters to neighbours and concerned parties seeking support to proceed with the project. It was a requirement of the consent that all of the contacted parties had no objections to the project. All letters sent to neighbours, Fish and Game NZ, and DOC were similar and included the same photos and Map.   For brevity maps and photos have not been duplicated on all of the letters exhibited in this appendix.**
3. **Finally the Horizon Regional council's decision is attached. This document includes a summary of the application charges and the conditions imposed on the project.**

10 September 2005

Tabitha Anthony
Horizons Regional Council
PO Box
Palmerston North

Resource Consent Application

Dear Tabitha

Further to my visit earlier this year please find attached our resource consent application for our research project at Kumeroa.

We already have a number of land based research projects operational in the Valley, my fellow researchers have been dealing with Derek Batchelor at the Tararua District Council regarding these projects.

We would be grateful if you could review these documents and advise of any further details you require. Our project sponsors would also be grateful for an estimate of the likely cost of this application.
Our project mentor Professor Ralph Sims will be handling the application and will provide a local point of contact.
You are very welcome to contact myself (021 2853581) or Ralph Sims at Massey University (06 3505288) if you have any further questions.

Yours sincerely

David Donnelly

Title: Assessment of Effects on the Environment
 Kumeroa DG
Author: David Donnelly

Revision History

Date	Version	Name	Comments
22/7/05	1.0	DRD	Initial draft release

Introduction
This Assessment of Effects on the Environment document accompanies the Resource Consent application to be sent to the Horizons Regional Council for the Kumeroa Distributed Generation project.
Each section below addresses the requirements in part 1 of the Fourth Schedule to the Act, section by section.
Assessment, section by section
(a) Description of the proposal
This Resource Consent Application relates to a research project led by Industrial Research Ltd and Massey University and funded by Mainpower Ltd and the New Zealand Government through the Foundation for Research Science and Technology.
The project involves the use of renewable and low environmental impact energy resources to provide support to the electricity grid. Its aim is to demonstrate how small communities can reduce their energy costs and reduce the need for electricity distribution companies to upgrade rural supply feeders.
This project will use the following technologies:
Micro Hydro turbine generator
Grid interactive inverter
All equipment is to be installed on the property of Prue and Mike Poulton, Totara Road, Kumeroa, legally described as Section 5 Blk 111 Makuri Survey District, SO13312.
A *Micro hydro turbine generator* will be located at 697862 (Behind Poulton's woolshed)
The water intake will be located at 698851 ('*Waterfall*'). on a small spring fed tributary that feds the Totara Valley Stream.
A polyethylene or polypropylene *pipeline*, not more than 63mm in diameter containing water will run above ground along the existing fence lines where possible and buried to a depth of at least 300mm where it is necessary to cross existing farm tracks.
Note that the 6 digit grid references above are taken from NZ map 260-T24 (Palmerston North). Figure 2 shows the proposed connection of equipment.

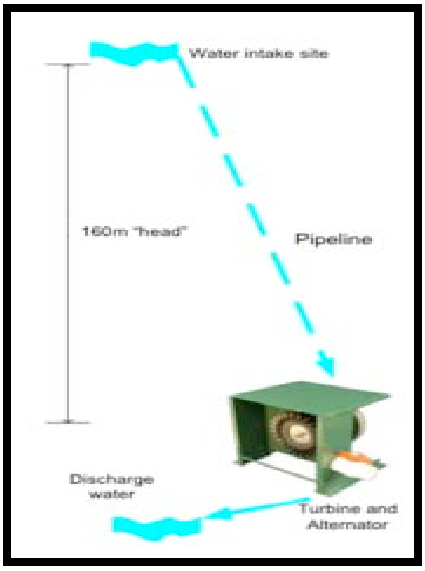


Fig 2 – Overview of project

Of particular interest from the point of view of this resource consent requirements are the following items:
Noise and visual impact of the Micro hydro turbine.
Visual impact of the pipeline
Extraction, Diversion and discharge of ground water
Impact of any dam structure.
(b) Alternative locations
Two alternative locations were investigated. We have chosen this site as it fulfils a number of technical research objectives. It is unlikely that this activity will result in any significant adverse effects on the environment at any of the locations investigated.
(c) Repealed
(d) Effect on environment
In this section the proposed technology explained and the effect on the environment is discussed.

Micro Hydro Turbine

We are intending to install a locally manufactured turbine/generator supplied by Eco-Innovations who are based in New Plymouth.
The turbine is unique as it is constructed from surplus Fisher and Paykel components that would otherwise be dumped in a landfill.
Numerous installations of these units have been completed worldwide.
The turbine is relatively small being approximately 0.6m x 0.6m x 0.3m outside dimensions.
It will be installed in a small shelter at the base of the valley.
In view of the small size and careful siting the unit will not be visible from neighbouring properties or the Poulton homestead. The visual impact of the turbine is therefore negligible.
A photograph of the unit is depicted in fig 2.

Fig 2 (courtesy EcoInnovation)

With respect to expected noise levels these have not previously been an issue and it has therefore proved unnecessary to formally document or measure these parameters. However, when operating the turbine noise levels can be expected to be similar to that produced from a domestic washing machine. As the unit will be partially enclosed and the nearest inhabited building is approximately 100m away we do not expect any problems with excessive noise.

The Micro Hydro turbine construction materials are listed in the table below:

Parameter	**material**
Generator Components	Stainless steel, Hardened steel, PVC, Magnetic materials, Copper electrical wiring.
Case	Aluminium Sheet
Pelton Wheel buckets	Polyethylene

Pipeline

We intend running a 1300m MDPE pipeline from the water intake site down to the turbine. The tubing used will be the standard black agricultural tubing that is widely used. It is already used extensively in the valley for irrigation purposes.
We expect the exterior diameter of the tubing to be no more than 75mm.
The tubing will be laid on the surface with consideration to minimising the visual impact and protection of the pipeline from vehicle and stock damage.
Where the pipeline passes under a roadway or vehicle track this depth will be increased to the appropriate depth prescribed in AS/NZS2566.2:2002. An exemption is requested from the requirements of section 4.3.3 of the same that requires all flexible pipelines to be buried to a depth of 600mm in land zoned for agricultural use.

Water Intake site

The proposed intake site will be at the top of the waterfall before the small tributary crosses the Farm track. In consideration of the small flow required we have decided not to build a weir. However we intend to rearrange some of the existing rocks in the stream to form a

small ponding area of approximately 600mm depth. This tributary has a number of existing waterfalls and ponding areas and we intended to preserve the character of the existing environment.
The intake assembly simply consists of a filter gauze on the end of a submerged pipe to prevent the ingress of pebbles and other small objects into the pipeline. there may also be a valve assembly to control water flow.
The intake assembly will not be visible from any of the surrounding properties. The remaining valves and pipeline are identical to existing farm water supply equipment.

Proposed Extraction and Discharge

Our calculations show an expected extraction rate of 1 litre per second. However for research purposes we seek consent to extract up to 2L/sec from this tributary.
(e) Hazardous substances
No hazardous substances are used on this project.
(f) Mitigation measures
Mitigation measures have been discussed throughout this document, particularly in section (d). We are confident that the installation of this equipment will have little effect on the residents and neighbours.
An open communication dialogue is maintained with the residents, Mike and Prue Poulton and Geoff and Marion Smith, who will advise of any adverse effects.

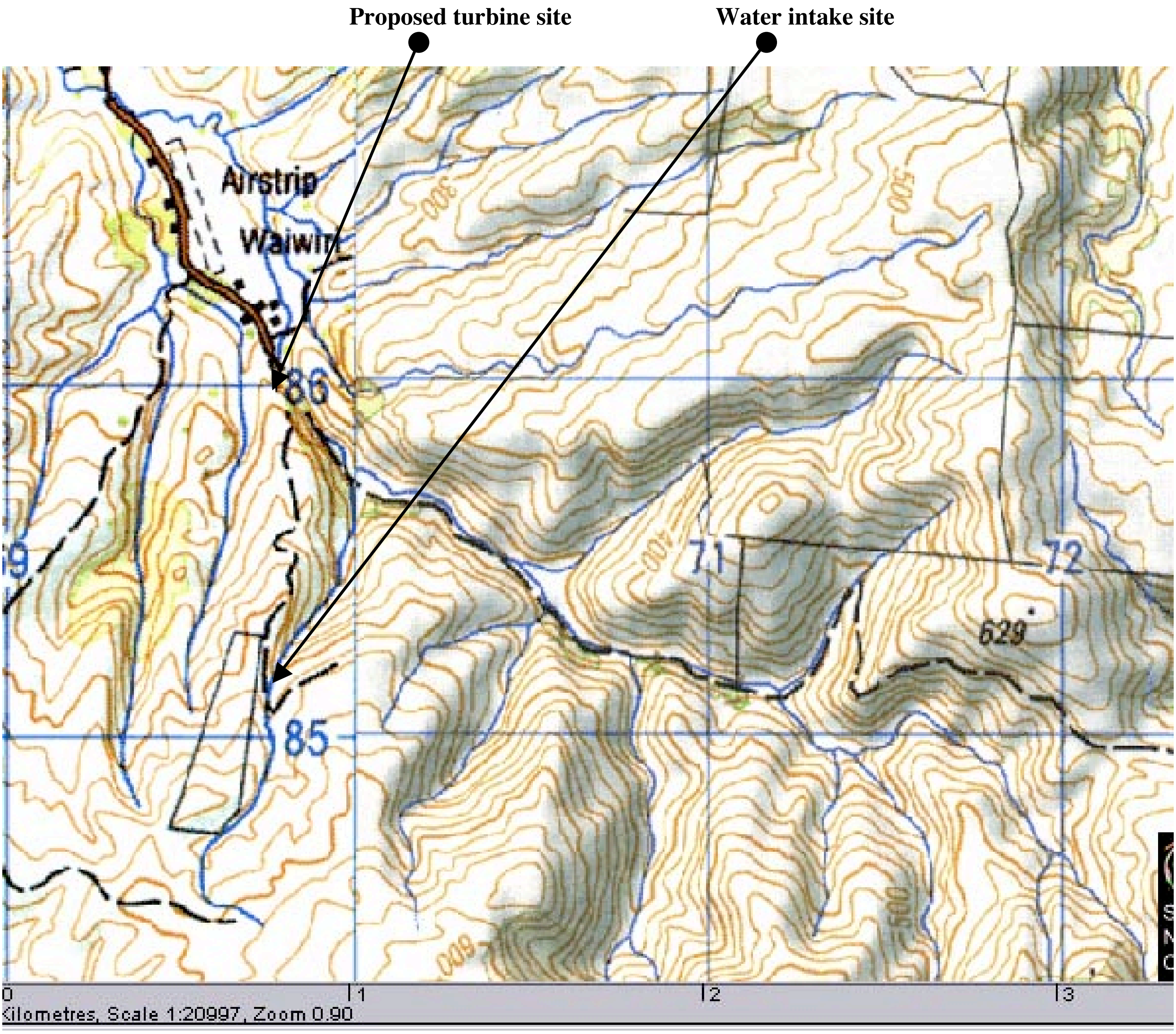
(g) Persons interested in or affected by the proposal

The following persons could be affected by the proposal:

Party	**Reason affected**	**Effect**	**Response**
M & P Poulton	Owners/users of land where equipment will be located	Several effects as discussed throughout this document	Verbal approval to proceed with project. Written approval to install wind turbine of greater than 10m height
G & M Smith	Neighbouring land owner/occupier	Possible visual impact of WTG mast >10m height	WTG installation approved (see attached approval document)
N and J Skerman			

(h) Monitoring of effects

The land owners and occupiers at the proposed site can monitor the effect of the system on them and have the authority and ability to shut down the equipment at any time if they perceive there are adverse effects due to the use of the equipment.
Additionally, this project is a component of a larger four year energy research project within the community, and the system operation will be closely monitored by the technology providers. This involves site visits by Massey University staff and students on at least a monthly basis.



Proposed turbine site
Water intake site
Airstrip
86
85
71
72
629
300
400
500
600
0
1
2
3
Kilometres, Scale 1:20997, Zoom 0.90

Centre for Energy Research
Massey University
Palmerston North

5 August 2005

Mr & Mrs Mike and Prue Poulton
Totara Valley Road
Kumeroa

Dear Mike and Prue,

Thank you for allowing us continued access to your property for our energy research projects.
As you are aware we are planning to install a Micro hydro turbine on your property.
The purpose of this letter is to explain what we wish to do and seek your permission to proceed with this project.
In line with your suggestion we have decided to take water from the top of the waterfall and pipe it down to a small turbine behind your woolshed. After the high pressure water has driven the turbine it will be discharged into the culvert that runs under the road and flows back into the Totara stream.
We intend to use standard black MDPE irrigation pipe and will endeavour to lay it to minimize visibility and ensure it has minimal effects on your farming operations. We will bury the pipe where it crosses farm tracks and other high traffic areas.
The turbine is a small assembly less than 1 m in height, a photograph (Fig 1) is attached for your reference. To accommodate the turbine we are hoping to use an existing site that currently houses the pump for an old sheep dipping station. There are already power lines there and the nearby culvert allows for simple discharge of water back into Totara Stream. I have attached a photograph of the proposed site for your consideration (Fig 2).
We anticipate housing the turbine in a small shed of no more than 4 square metres floor area.
When operating on the continuous basis we expect the turbine will produce around 24 units of electricity per day. This is typically sufficient to power 1 or 2 households.
We are confident the project will not have any impact on the enjoyment of your property. However, in the unlikely event that you have any issues with the operation of the project we would of course shut the plant down and work to resolve your concerns.
With respect to timing, if I can successfully arrange a Resource Consent over the next month I anticipate installing the system during September/October.

If you are happy for us to proceed I would be grateful if you can sign the attached consent form and return it in the envelope supplied.
Should you have any questions or wish to discuss any aspects of the project further you are very welcome to contact me on 09 9140735 or contact Ralph Sims at Massey University directly on 06 350 5288.

Regards

David Donnelly
Project Manager

Confirmation of Approval

Mr and Mrs Mike and Prue Poulton being the landowners give our permission for Massey University to proceed with the Micro Hydro research project on our property as outlined in this document.

Signed ………………………………………………………………………………..

Date ……………………………………

Photographs of proposed Micro Hydro project.

Fig 1. Proposed Turbine Courtesy EcoInnovations

Fig 2. Proposed site for turbine shed

Centre for Energy Research
Massey University
Palmerston North

5 August 2005

Geoff and Marion Smith
Croftlea farm
514 Totara Valley Road
Kumeroa

Dear Geoff and Marion

Further to our renewable energy projects in your valley a partnership comprising IRL, Main Power and Massey University are investigating installing a small research hydro electric system on Mike and Prue Poulton's property.
To simplify the resource consent process and keep you informed of our activities we would like to seek your approval as neighbouring land owners.
The installation comprises a water intake at the top of the waterfall on Poulton's property and a small MDPE irrigation pipe running down the fence line to transport the high pressure water into a turbine located behind Poulton's woolshed. All of the water is then discharged back into the Totara Stream. The turbine is less than one metre high and photographs are attached to show you what the system will look like.
We do not expect this project will have any impact on neighbouring property owners as it will not be visible from your property. It will have no effect on total water flows in the Totara stream.
We would be very grateful if you can sign and return the attached approval, which will allow us to proceed with our Resource Consent application. Please find attached a prepaid envelope for your convenience.
If you have any questions you are very welcome to contact me on 09 9140735 or contact Ralph Sims directly on 06 350 5288 at Massey University.
Thank you for your support, I look forward to continuing Massey University's involvement with the Kumeroa community.

Regards

David Donnelly
Project Manager

I ………………………………………………… being a neighbouring landowner give my approval to Massey University to proceed with a Micro Hydro project on Mike and Prue Poulton's property as outlined in this document.

Signed …………………………………………………….
Date ……………….

Centre for Energy Research
Massey University
Palmerston North

5 August 2005

Palmerston North Office
Fish and Game New Zealand
PO Box 1325
Palmerston North

Attention: Kate McArthur, Field Officer

As part of our renewable energy research project in the Totara Valley Massey University are investigating installing a small research hydro electric system on Mike and Prue Poulton's property at Kumeroa (near Woodville).
To simplify the resource consent process and keep you informed of our activities we would like to seek your approval as an interested party.
The installation comprises a water intake at the top of a waterfall on Poulton's property and a small MDPE irrigation pipe running down the fence line to transport the high pressure water into a turbine located behind Poulton's woolshed. All of the water is then discharged back into the Totara Stream. The turbine is less than one metre high and photographs are attached to show you what the system will look like.
We do not expect this project will have any significant environmental effects as the project will have no impact on water quality or water flow volumes in the Totara stream.
I have attached our assessment of environmental impacts report and extracts of a previous Massey University study on the Totara Stream for your reference.
We would be very grateful if you can sign and return the attached approval, which will allow us to proceed with our Resource Consent application. Please find attached a prepaid envelope for your convenience.
If you have any questions you are very welcome to contact Professor Ralph Sims on 06 350 5288 at Massey University or myself directly on 09 9140735.

Regards

David Donnelly
Project Manager

Confirmation of Approval

………..………………………………………………. give our approval for Massey University to proceed with a Micro Hydro research project on Poulton's property as outlined in this document.

Signed ………………………………………………………………………………..

Date ……………………………………..

Centre for Energy Research
Massey University
Palmerston North

5 August 2005

District Conservator
Wellington Conservancy
Department of Conservation
PO Box 5086
Wellington

Attention: Geoff Flavell, Community Relations Manager

As part of our renewable energy research project in the Totara Valley Massey University are investigating installing a small research hydro electric system on Mike and Prue Poulton's property at Kumeroa (near Woodville).
To simplify the resource consent process and keep you informed of our activities we would like to seek your approval as an interested party.
The installation comprises a water intake at the top of a waterfall on Poulton's property and a small MDPE irrigation pipe running down the fence line to transport the high pressure water into a turbine located behind Poulton's woolshed. All of the water is then discharged back into the Totara Stream. The turbine is less than one metre high and photographs are attached to show you what the system will look like.
We do not expect this project will have any significant environmental effects as the project will have no impact on water quality or water flow volumes in the Totara stream.
I have attached our assessment of environmental impacts report and extracts of a previous Massey University study on Totara Stream for your reference.
We would be very grateful if you can sign and return the attached approval, which will allow us to proceed with our Resource Consent application. Please find attached a prepaid envelope for your convenience.
If you have any questions you are very welcome to contact Professor Ralph Sims on 06 350 5288 at Massey University or myself directly on 09 9140735.

Regards

David Donnelly
Project Manager

Confirmation of Approval

………..………………………………………………. give our approval for Massey University to proceed with a Micro Hydro research project on Poulton's property as outlined in this document.

Signed ………………………………………………………………………………..

Date ……………………………………….

Centre for Energy Research
Massey University
Palmerston North

5 August 2005

N and J Skerman
Totara Valley Road
Kumeroa

Dear Nick and Jan,

Further to our renewable energy projects in your valley a partnership comprising IRL, Main Power and Massey University are investigating installing a small research hydro electric system on Mike and Prue Poulton's property.
To simplify the resource consent process and keep you informed of our activities we would like to seek your approval as neighbouring land owners.
The installation comprises a water intake at the top of the waterfall on Poulton's property and a small MDPE irrigation pipe running down the fence line to transport the high pressure water into a turbine located behind Poulton's woolshed. All of the water is then discharged back into the Totara Stream. The turbine is less than one metre high and photographs are attached to show you what the system will look like.
We do not expect this project will have any impact on neighbouring property owners as it will not be visible from your property. It will have no effect on total water flows in the Totara stream.
We would be very grateful if you can sign and return the attached approval, which will allow us to proceed with our Resource Consent application. Please find attached a prepaid envelope for your convenience.
If you have any questions you are very welcome to contact me on 09 9140735 or contact Ralph Sims directly on 06 350 5288 at Massey University.
Thank you for your support, I look forward to continuing Massey University's involvement with the Kumeroa community.

Regards

David Donnelly
Project Manager

Confirmation of Approval

I/We………………………………………………. being neighbours of the Poultons on Totara Road, Kumeroa, give our permission for Massey University to proceed with a Micro Hydro research project on Poulton's property as outlined in this document.

Signed ……………………………………………………………………………..

Date   …………………………………….

4/1/MAS
ELC:MET

21 November 2005

Resource Management Act 1991

Decision on an Application

for Resource Consent

Applicant:
Massey University
Institute of Technology and Engineering
Private Bag 11-222
PALMERSTON NORTH

Application No: 103504 for a Water Permit (surface take)
103505 for a Water Permit (divert)
Location: Totara Stream, Totara Road, Woodville
Catchment No: 325240
Legal Description: Lot 1 DP 23476 Blks XIV XVII Tahoraiti SD Lots 3 4 5 DP 23247 Sec 9 Blk III Secs 1 2 58 Blk XVI Makuri SD Pt Sec 8 9 XVII Tahoraiti SD
Valuation No: 11350/096/00
Map References: T24:694-864
Regional Policy Statement: Objective 12 and 16
Policies 12.1 – 12.4, 16.1 and 16.2
Regional Plans: Land and Water Regional Plan
Beds of Rivers and Lakes
Regional Rules: SW Rule 5
BRL Rule 10
Activity Type: Discretionary

This non-notified application for resource consent (Water Permit) is for an activity restricted under Section 14 of the Resource Management Act and SW Rule 5 of the Land and Water Regional Plan.

The Application

The Applicant, Massey University seek two Water Permits to divert 22% of the flow of the Totara Stream and to abstract up to 172.8 cubic metres (172.8m^3) of surface water per day at a rate of 2 litres per second (2L/sec) from the Totara Stream for the operation of a small hydro-electric power plant.

The proposed intake site will be at the top of the waterfall before the small tributary crosses the farm track. The Applicant intends to rearrange some of the existing rocks in the stream to create a small ponding area of approximately 600mm depth. Less than 10 cubic metres of water will be stored behind this structure. The Applicant intends to minimise the discharge of sedimentary material into the stream during construction and to preserve the character of the existing environment.

A polyethylene or polypropylene pipeline, not more than 63mm in diameter containing water will run above ground along existing fence lines where possible and be buried to a depth of approximately 300mm where it is necessary to cross existing farm tracks.

The pipeline will run to a Pelton water turbine which will be installed in a small shelter at the base of the valley. The turbine will measure approximately 0.6m x 0.6m x 0.3m.

The Applicant states that the total flow rate measured on the tributary during April was between 9 and 10 litres per second. The planned extraction rate would result in a maximum of 22% of the total flow being diverted.

The Applicant has sought a term of 20 years for these Water Permits.

Non-Notification

The Applicant has obtained the unconditional written approval of the Department of Conservation, Fish and Game New Zealand, and the adjoining land owners and occupiers, M and P Poulton and G and M Smith.

The Regional Council's Environmental Scientist and the Consulting Engineer were satisfied that the adverse effects of the proposed abstraction would be minor. The Regional Council's Consents Planner agreed that as the approval of all potentially affected parties had been obtained the application could therefore be processed on a non-notified basis in accordance with Section 94(2) of the Act.

Environmental Effects

Surface Water Abstraction

The Regional Council's Environmental Scientist has assessed and reported on the application to abstract surface water from the Totara Stream.

The Environmental Scientist notes that the Applicant proposes to construct a small hydroelectric power plant drawing water from and discharging water to the Totara Stream. He notes that the proposal seeks to take water via a 63mm diameter polypropylene pipe located in a small pool at the head of a waterfall.

The Environmental Scientist notes that the pipe will be located next to an existing fence line and will drop the water 165m to the generator plant. The pipeline is proposed to be approximately 1,300mm long and will discharge the water back to the stream at a point approximately 20m downstream of the generating site, 1,300m downstream of the intake site. The maximum rate of abstraction sought is 2L/s, which is equivalent to a maximum take rate of up to 172.8m^3/day.

As the take will be returned to the stream the Environmental Scientist considers that its environmental effect will be limited to the area between the intake and discharge points. Therefore he considers that one of the main factors to be considered for a take of this type is the impact on fish passage. The assessment of environmental effects supplied by the Applicant outlines that the Totara Stream has a number of natural waterfalls that preclude the existence of migratory fish species. In this case, the fall for the pipeline is estimated at 163m. From this it is assumed the height of the waterfall is in the same order and therefore excludes any migratory species.

The Environmental Scientist reports that the stream flow is estimated by the Applicant to be between 9-10L/s with little year round variation. Therefore, the planned abstraction rate of 2L/s equates to approximately 22% of the stream flow. Further, it is noted by the Applicant that the actual rate of abstraction may be lower with an expected abstraction rate of 1-1.5L/s. The Environmental Scientist therefore considers the environmental effects of abstracting 2L/s from approximately 1,300m of the stream are likely to be minimal.

The Environmental Scientist notes that the Totara Stream is valued trout spawning stream. However as the water abstracted is all returned to the stream the effect of this activity on the trout spawning should be minimal. If fish (e.g. non migratory species) are present in the stream the installation of a screen will prevent damage to fish as a result of the abstraction. Therefore, the Environmental Scientist has recommended a consent condition requiring the installation of a 5mm screen on the intake pipe.

The Environmental Scientist reports that water metering is an essential mechanism for monitoring the surface water resource. He reports that in order to make informed decisions regarding water allocation it is necessary to monitor abstractions of water particularly in pressure areas such as the Upper Manawatu Catchment. The Scientist reports that water metering is recommended for this take to provide for a telemetered water meter on the pipe that transfers water from the point of abstraction to the pelton. He reports that this will measure the entire volume abstracted and the rate at which it is abstracted. The Scientist reports that this in turn will provide the Regional Council with the necessary information to quantify the volume abstracted and to manage the impact of the abstraction on the environment in a manner that addresses the potential for adverse effects to occur.

The Regional Council's Environmental Scientist recommends that this Water Permit be granted for a term of 20 years. He notes that this term is consistent with the length of many of the recently granted consents in this catchment. The Environmental Scientist recommended conditions to restrict the volume and rate of abstraction as well as monitoring conditions. He has also recommended the conditions of the Permit be reviewed in November 2011, 2016 and 2021 to address significant adverse effects of the abstraction that may arise as a result of the exercise of the Permit. The Applicant should note that reviews may reduce the volume and rate of abstraction granted but not to a level that makes electricity generation an unviable option.

Stream Diversion

The Regional Council's Consulting Engineer has assessed and reported on the application for a Water Permit to divert the Totara Stream.

The Consulting Engineer notes that the intake will involve the placement of a 63mm polypropylene pipe into a small pool at the head of a waterfall on the stream. He notes that the pipe will be screened to prevent stones and debris from entering the pipeline. The pool will be enlarged by rearranging some existing rocks in the stream.

He notes that the pipe will be laid on the ground adjacent to an existing fence line and will drop the water 165m to the generating plant before discharging the water back to the stream. No details are provided for the discharge point.

The Consulting Engineer notes that the proposal will have minimal adverse effect on the environment. He considers that the intake flow will reduce the flow in the stream by approximately 22%. The Stream has a number of waterfalls which prevent fish passage, therefore he considers that the reduction in flow will not have an additional effect on fish passage.

The Consulting Engineer notes that the application does not describe the outlet structure but as only 2L/sec will be discharged, he considers that the effects of such an activity will be no more than minor.

The Consulting Engineer recommends that the Water Permit to divert 22% of the Totara Stream be granted subject to recommended conditions to avoid remedy or mitigate any adverse effects that have the potential to be significant for a term of 20 years for use and maintenance of the works.

Planning Assessment

Section 104 Considerations

Section 104(1) of the Resource Management Act 1991 outlines the matters that the Consent Authority is to have regard to when considering applications for resource consent, subject to Part II of the Resource Management Act.

The Regional Council’s Consents Planner has assessed the application with respect to the relevant Statutory Planning matters under Section 104 and an assessment of the application against these matters. Note that only relevant sections, or parts of sections of statutory documents as applicable to this resource consent have been reproduced in this report.

(a) Actual and potential effects on the environment

The actual and potential effects on the environment of allowing the activities relating to the proposal are outlined above in the Environmental Effects Section of this decision.

(b)(iii) Regional Policy Statement

Objective 12 of the Regional Policy Statement is to maintain or enhance flows in rivers and streams at a level that safeguards their life supporting capacity and avoids, remedies or mitigates any adverse effects on the environment. This objective is implemented by Policies 12.1, 12.2, 12.3 and 12.4.

Policy 12.1 enables the taking of surface water while sustaining flows and life supporting capacity and avoiding, remedying or mitigating adverse effects. Policy 12.2 enables consideration of efficiency of use and the availability of the resource for other users. Of particular note is Policy 12.3 that enables the setting of minimum flows and/or maximum rates of use where this is necessary to achieve the purpose of the Act with regard to the existence of conflicts between major users and in-stream use. It is possible that through policy development later reviews may result in the imposition of minimum flows on this permit.

Objective 16 and Policies 16.1 and 16.2 of the Regional Policy Statement seek to ensure that the adverse effects of structures on rivers and streams are avoided, remedied or mitigated.

Objective 34 is to promote a consistent approach to the duration of resource consents. Policy 34.1 allows for small takes of surface water of less than 200 cubic metres per day to be granted a term of up to 20 years. Granting a term of 20 years is consistent with that applied for by the Applicant and the term recommended by both the Environmental Scientist and the Consulting Engineer with Policy 34.1 of the Regional Policy Statement for the Manawatu-Wanganui Region.

Subject to compliance with conditions of consent the proposed activity will not conflict with the objectives and policies of the Regional Policy Statement for the Manawatu-Wanganui Region.

(b)(iv) Regional Plans

Land and Water Regional Plan

The proposed activity requires consideration under the Land and Water Regional Plan. A Water Permit is required for this abstraction pursuant to SW Rule 5 of the Land and Water Regional Plan that provides for surface water abstraction in excess of 15m^3 per day as a Discretionary Activity.

SW Objective 1 of the Land and Water Regional Plan is to maintain flows in rivers to maintain or enhance their existing life supporting capacity.

SW Policy 2 of the Land and Water Regional Plan requires that particular matters be considered when assessing an application for a Water Permit. These considerations include the effects of the activity on the natural flow regime, the duration of low flows, significant aquatic habitat for trout during low flows and natural character. It also requires consideration of whether the proposed activity would adversely affect the specified values of any regionally significant river or lake identified in the Regional Policy Statement and the social and economic well being and the health and safety of people and communities. In isolation this take is not in conflict with this Policy. Any cumulative impacts are managed by water metering and can be addressed via review if they are significant.

The Regional Council's Environmental Scientist has recommended flow metering, monitoring conditions and a review of permit conditions that may reduce the rate or volume of the abstraction authorised by the consent. The Applicant should be aware that such reductions cannot be of a magnitude to make the permit unviable.

Regional Plan for the Beds of Rivers and Lakes and Associated Activities

Objective 3 of the Regional Plan for the Beds of Rivers and Lakes and Associated Activities enables the use and development of river beds while ensuring adverse effects are avoided, remedied or mitigated.

Policy 2 of the Plan provides guidance for assessing resource consent applications. These matters have been considered in the assessment of this application.

As the length of the permanent diversion of flow from the stream is greater than 100 metres the Applicant could not meet the performance conditions of BRL Rule 9 (i), the activity requires a consent pursuant to BRL Rule 10.

The proposed activities are not considered inconsistent with the objectives and policies of the Regional Policy Statement for Manawatu-Wanganui, the Proposed and Operative Land and Water Regional Plan or the Regional Plan for Beds of Rivers and Lakes and Associated Activities.

Relevant Part II Consideration

Part II of the Act sets out the purposes and principles of the Act. Section 104 the Act is subject to Part II. The matters contained in Part II of the Act have been taken into account in the assessment of this application. The proposed activity is not considered to be inconsistent with these matters.

Recommendation

It is recommended that these resource consent applications be granted for a term of 20 years, subject to conditions of consent for the following reasons:

The activities will have minor actual or potential adverse effects on the environment.
The activities are not contrary to any relevant plans or policies.
The activities are consistent with the purpose and principles of the Resource Management Act 1991.

Costs

Section 36 of the Act provides for the recovery of extra costs from an Applicant when an application deposit is inadequate to meet the actual and reasonable costs of processing the application. In this case the Applicant did not pay a deposit.

The costs incurred by the Regional Council in processing this application were:

Staff Time

Consents Planner 6 hours @ $84.00 per hour	$ 504.00
Environmental Scientist 2.5 hours @ $89.00 per hour	$ 222.50
Consulting Engineer 1 hour @ $85.00 per hour	$ 85.00
Consents Administrator 1.5 hours @ $79.00 per hour	$ 118.50
Team Leader Consents 1.5 hours @ $94.00 per hour	$ 141.00
Administration	$ 75.00

Sub Total (Excl GST)	$ 1,146.00
GST	$ 143.25
Total Costs Owing (Incl GST)	**$ 1,289.25**

The Decision

A. The Team Leader Consents of the Manawatu-Wanganui Regional Council (trading as Horizons Regional Council) has considered this non-notified application. On 21 November 2005 the Team Leader, pursuant to delegated authority under Section 34A of the Resource Management Act, grants Water Permits 103504 and 103505 pursuant to Section 104B of the Act, to Massey University to abstract surface water from the Totara Stream, located in the Totara Valley, Woodville and to divert surface water in the Totara Stream via a polypropolene pipeline for the purpose of running a hydro-electric power plant for a term expiring on 21 November 2025 subject to the following conditions:

The activities authorised by these Water Permits is restricted to the maximum daily (midnight to midnight) abstraction of surface water from the Totara Stream via an intake, not exceeding 172.8 cubic metres per day (172.8m^3/day) and the diversion of flow in the Totara Stream via existing a polypropolene pipeline, on land legally described Lot 1 DP 23476 Blks XIV XVII Tahoraiti SD Lots 3 4 5 DP 23247 Sec 9 Blk III Secs 1 2 58 Blk XVI Makuri SD Pt Sec 8 9 XVII Tahoraiti SD at approximate map reference T24:694-864 and in general accordance with the application except as otherwise required by conditions of these Water Permits.

Subject to Condition 1 the maximum rate of abstraction shall not exceed 2 litres per second (2L/sec).

By **1 March 2006** the Permit Holder shall install and maintain, in fully operational condition, a flow meter with a pulse counter output on the water abstraction line traceably calibrated to +/- 5% or better. The flow meter shall be able to provide daily water use as well as a pulse counter output. The flow meter shall be positioned to measure the entire volume abstracted by this consent only.

Note: Horizons Regional Council may attach monitoring equipment / telemetry to monitor water use to ensure compliance with Water Permit conditions and as part of a programme to enable monitoring of total catchment water use.

The Permit Holder shall keep an accurate record of the daily water volumes abstracted from the Manawatu River. If no water is taken a ‘Nil’ measurement shall be recorded. A copy of this log is to be sent to the Manawatu-Wanganui Regional Council’s Team Leader of Compliance Monitoring within 10 working days of the end of each calendar month and upon request.

The Permit Holder shall provide the Manawatu-Wanganui Regional Council’s staff or its agents with reasonable access to enable monitoring of water use.

The Permit Holder shall ensure that the intake pipe is screened with a minimum screen size of 5mm to prevent damage to trout and native fish as a result of the abstraction.

The Consent Holder shall ensure that the outlet flow into the stream does not cause any erosion of the stream channel.

The Consent Holder shall ensure that:

a. No machinery leaking fuel, lubricants, hydraulic fluids or solvents shall work within a watercourse, or in an area where leakage could enter a watercourse;
b. No refuelling of any vehicles, machinery or equipment shall take place within the bed of the watercourse or in a position where spills may enter water;
c. The storage of fuel or contaminants adjacent to a watercourse does not result in any fuel or contaminants entering water; and
d. During construction any machinery or equipment not in use shall be stored out of the riverbed.

The Manawatu-Wanganui Regional Council may, under Section 128 of the Act, initiate a review of all conditions of this Permit annually in the months of November in the years 2011, 2016 and 2021. The reviews shall be for the purpose of reviewing the effectiveness of the conditions in avoiding, or mitigating any adverse effects on the environment which may arise as a result of the exercise of this Permit;

The review may be necessary to:

i. assess the water abstraction volumes and rates detailed in Conditions 1 and 2 of this Permit for consistency with any review of the Regional Water Allocation Policy developed, and if necessary change the monitoring outlined in Conditions 3, 4 and 5 of this Permit;
ii. deal with any significant adverse effects, including cultural effects, on the environment which may arise as a result of this Permit; and

The review of conditions shall allow for:

i. the deletion or amendment of any of the conditions of this Permit including reduction in abstraction volume and/or rate; or
the addition of new conditions as necessary to avoid, remedy or mitigate any adverse effects on the environment.

Note: Any review exercised under this condition may result in the abstraction volume and/or rate being reduced and/or restricted, or further restrictions being placed on the abstraction volume and/or rate during low flow conditions.

The Regional Council may under Section 128(1)(b) of the Resource Management Act 1991, initiate a review of all of the conditions of this Permit at any time throughout the term of this permit, when a regional plan has been made operative which sets rules relating to maximum or minimum levels or flows or rates of use of water and in the Regional Council's opinion it is appropriate to review the conditions of the permit in order to enable the levels, flows, rates, or standards set by the rule to be met. The review shall be for the purpose of reviewing the effectiveness of the conditions in avoiding, or mitigating any adverse effects on the environment, which may arise as a result of the exercise of this Permit in response to any future Regional Water Allocation Plan.

Charges, set in accordance with Section 36(1)c of the Resource Management Act 1991, and Section 150 of the Local Government Act 2002, shall be paid to Manawatu-Wanganui Regional Council for the carrying out of its functions in relation to the administration, monitoring and supervision of this resource consent and for the carrying out of its functions under Section 35 (duty to gather information, monitor, and keep records) of the Act.

[**Note:** Section 36(1)c of the Act provides that Manawatu-Wanganui Regional Council may from time to time fix charges payable by holders of resource consents. The procedure for setting administrative charges is governed by Section 36(2) of the Act and is currently carried out as part of the formulation of Manawatu-Wanganui Regional Council's Long Term Council Community Plan.]

B. The Team Leader Consents resolved pursuant to Section 34 of the Act that the actual and reasonable costs of processing this Water Permit shall be recovered from Massey University amounting to $1,289.25 (Incl GST).

Reasons for these Decisions

In making her decision on these applications pursuant to Section 104B of the Resource Management Act, the Team Leader Consents had regard to matters as required by Section 104 of the Act. In particular the Team Leader considered the actual and potential adverse environmental effects associated with granting these Water Permits.

The proposal will not conflict with the objectives and policies of the Proposed and Operative Land and Water Regional Plan. The Team Leader considers the consent conditions will ensure that the potential adverse effects of this abstraction will be no more than minor. The Team Leader is satisfied that granting a Permit for this activity will not be inconsistent with the sustainable management provisions provided in Part II of the Act.

The Team Leader is aware that the Environmental Scientist considers that there will be no adverse effects created by the proposed abstraction as it is such a small amount of the extrapolated low flow of the Totara Stream. She is aware that the Scientist and Consulting Engineer consider that there will be no adverse effects on the quantity, quality or in-stream habitat from either the diversion structures or the water abstraction.

To avoid the potential for impacts on flow levels, life supporting capacity and habitat values the Team Leader has imposed conditions relating to abstraction rates and monitoring. The provision for review will provide the opportunity to review the abstraction volume or rate should any significant adverse effects arise during the term of the Permits. The provision also provides for a review should this be required under future water allocation policy within a Regional Plan.

The Team Leader Consents notes that the term imposed is consistent with Policies 34.1 and 34.2 of the Regional Policy Statement and with terms imposed on similar sized permits with similar actual and potential effects within the catchment and Region. She notes that Horizons Regional Council is currently undertaking research and policy development that may alter the amount of water available for abstraction in the future. The Permit Holder should be aware that there is no guarantee that a permit for this volume of water will be granted in the future.

The Team Leader has recommended recovering the actual and reasonable costs incurred in relation to the processing of this Permit. The Team Leader believes the costs in relation to the processing of this Permit to be both fair and reasonable. She notes that further charges relating to research, monitoring and administration may be incurred during the lifetime of this Permit.

The Team Leader is satisfied that provided conditions of this Permit are met, granting consent for this activity will not be inconsistent with the Regional Policy Statement for the Manawatu-

Wanganui Region, the Land and Water Regional Plan and the Regional Plan for Bed of Rivers and Lakes and Associated Activities.

Sarah Gardner
TEAM LEADER CONSENTS

21 November 2005

Appendix 2 Vector distributed generator agreement

The vector agreement is a concise example of the distributed generation agreements now available on distribution company web sites. It is presented because it encompasses a good summary of the connection process and requirements.

Distributed Generation (≤10kW)
Connecting to Vector's electricity network

Important information
about installing distributed generation
with capacity of 10 kilowatts or less

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Contents

What is distributed generation?

- You can generate electricity for your own use, while still being connected to Vector's electricity network and may be able to sell any surplus electricity you produce to an electricity retailer (Vector cannot purchase your electricity under government regulation). This is known as distributed generation.

- The electricity you may sell from your distributed generation system is distributed on the network of your lines company. Vector is the lines company for three regions:
  - **Auckland** (Auckland City, Manukau City and parts of Papakura District)
  - **Northern** (North Shore City, Waitakere City and Rodney District)
  - **Wellington** (Wellington City, Hutt City, Upper Hutt City and Porirua City)

  NOTE: **Vector operates its Northern and Wellington regions under the UnitedNetworks brand, but your query will be handled by a Vector representative.**

- The following information applies to distributed generation. It does not apply to electricity generating systems that stand alone (known as islanded networks) and do not connect to Vector's networks.

- This information applies to distributed generation using a single-phase electricity generating system with maximum generation capacity of 10kW or less. It is likely to be installed in residential or small business premises. **For larger distributed generation systems, please refer to our documentation for distributed generation with a capacity of greater than 10kW or call (09) 303 0626.**

Generating and selling your own electricity - before you start

- Ensure that your distributed generation will not cause safety problems.

- You will need to arrange with your electricity retailer, who is authorised to trade on Vector's electricity networks, to purchase the surplus electricity you generate.

- You must use a registered electrician to install your distributed generation system and you will need to get an electrical Certificate of Compliance (COC).

The following information details the steps you must follow before installing or connecting your distributed generation system to Vector's network.

If you have any queries or need more information, please call (09) 303 0626.

Standards

There are various standards that you need to meet to be able to connect you to distributed generation. These standards are:

AS 4777.1	Grid connection of energy systems via inverters - Installation requirements
AS 4777.2	Grid connection of energy systems via inverters - Inverter requirements
AS 4777.3	Grid connection of energy systems via inverters - Grid protection requirements
AS/NZS 3000	Electrical installations (known as the Australian/New Zealand Wiring Rules)

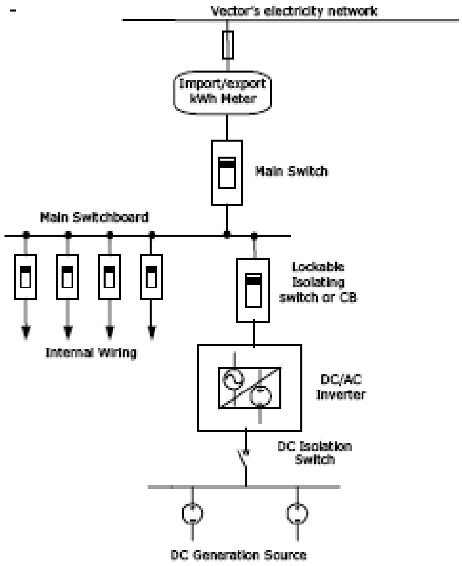
These standards apply to small distributed generation where the system is connected to the electricity network via an inverter. Other standards will apply where the generator is connected directly to the network.

Copies of the relevant standards are available from **www.standards.com.au**

Specific Technical Requirements:

- The distributed generation system must have a lockable isolating switch or circuit breaker accessible by Vector's field service crews.
- The inverter unit must be sealed in such a way that the protection settings cannot be adjusted without the unit being removed.
- For further details, please consult Vector's 'Technical Requirements for Connection of Distributed Generation', which is available on **www.vectorelectricity.co.nz**

≤10kW inverter connected distributed generation – wiring diagram



Safety

Your distributed generation system will feed electricity into Vector's network. For everyone's safety, Vector must be notified of your connection to our network. This ensures our linesmen know about the possibility of live electricity coming from your generator when they are working on the network lines in your area.

Without that knowledge, live electricity from your distributed generation system could be feeding into a section of our network where all other sources of electricity are inactive. This live electricity could electrocute a linesman.

For everyone's safety your generating system must, as a minimum, meet statutory requirements, comply with international manufacturing standards and meet safety standards specified by Vector. Not all distributed generation systems have the necessary safety mechanisms for use on a distribution network in New Zealand, so more details about Vector's minimum required standards are on page 7.

Four steps to generating and selling your own electricity

A guide to installing distributed generation with a capacity of 10kW or less

STEP 1 – Select your system	Solar panels (photovoltaic), small wind and micro-hydro generators are the most commonly used systems for distributed generation. More information on page 7.
STEP 2 – Talk to your electricity retailer	You will need to discuss: • Supply of import/export meters • Sale of surplus energy • The tariff they will apply More information on page 8.
STEP 3 – Arrange installation	You must: • Use a registered electrician • Comply with all relevant regulations and standards • Get an electrical Certificate of Compliance (COC) More information on page 8.
STEP 4 – Notify Vector once connected	You must send Vector: • A completed copy of the 'Notification of Connection – Distributed Generation (≤10kW)' • A copy of the electrical Certificate of Compliance (COC) Your registered electrician can complete this information for you. Vector will process this information for you free of charge. More information on page 9.

Step 1 – Select your system

Solar panels, also known as photovoltaics, are the most commonly used systems for distributed generation of 10kW or less. Small wind systems and micro-hydro generators can also be used.

These systems are available from various suppliers. Please note that Vector can take no responsibility for any claims or information provided by your supplier. We advise that you talk to your registered electrician and compare the specifications of various products before deciding on a system.

Minimum standards

Your surplus electricity will flow onto Vector's distribution network. Therefore, your system must, as a minimum, comply with Vector's 'Technical Requirements for Connection of Distributed Generation', Vector's 'Distribution Code' and AS 4777.2 and AS 4777.3 standards.

Vector recommends that you familiarise yourself with these documents so that you can make an informed decision when choosing your distributed generation system.

Safety standards

Your system needs to comply with the standards of AS 4777.2 and 4777.3 to ensure safety for use on Vector's network.

Systems that comply with these standards are classified as 'non-islanding' systems. This means your distributed generator will automatically isolate itself if there is a power outage on the section of Vector's network you are connected to. It also means your system will not reconnect to Vector's network until we have restored the supply.

This allows our linesmen to isolate a section of line so they can safely work on it without the potential for your distributed generator to backfeed live electricity into that section of line and electrocute the linesman.

To avoid such safety risks and potential harm, your system will need to comply with the specified standards, be installed by a registered electrician and Vector must be notified when your system has been connected.

Step 2 - Talk to your electricity retailer

Any surplus electricity you generate may be sold back to your electricity retailer. You will need to arrange with your electricity retailer to take receipt of or purchase your surplus electricity. Vector is able to inform you of which electricity retailers operate in your area. You will need to complete those arrangements before your system can be connected to Vector's network.

A new meter

Your electricity retailer may need to install a new meter. This new meter will be able to measure the amount of surplus electricity that you generate and sell back.

An import/export meter is the minimum requirement for use with distributed generation systems. An import/export meter has the capability to measure both imported and exported volumes of energy. This ensures you receive the correct payment for the electricity you contribute to the electricity retailer and that you are charged correctly when you use electricity supplied by the retailer.

There may be extra rental costs for this type of meter and your electricity retailer will advise you about these. You may also have to pay your electricity retailer a tariff or meter change fee, depending on your location and your current metering configuration.

Distribution lines charges

Your lines charges from Vector will be based on the energy that is supplied to you from the distribution network. This is the amount of energy recorded in the import register of your import/export meter.

Step 3 - Arrange installation

The system you choose should include manufacturer's installation instructions. To comply with all the necessary building and electrical codes and standards, you must use a suitably qualified installer. You must also check with your local Council to find out if any building or other consents may be required.

A registered electrician must do all wiring associated with the system. The wiring must comply with AS/NZS 3000 or any successive standard or legislation.

Meeting the standard

Your registered electrician needs to comply with AS 4777.1 when installing your system. While AS 4777.1 deals primarily with the connection of inverter-based systems, it is equally applicable to distributed generation systems that do not use inverters. The purpose of complying with this standard is to ensure safety when your system is connected to the network, and to prevent accidents on the network or damage to your equipment in the future.

If your distributed generator continued to operate after a network fault, your system could liven up Vector's electricity network at a time it was assumed to be de-energised. This could lead to a serious accident for anyone working on the network, and/or damage to your equipment. A system manufactured to AS 4777.2, including protection systems installed in accordance with the AS 4777.3, will provide isolation and prevent this happening.

Step 4 - Notify Vector once connected

As your distributed generation system will be connected to Vector's network, we need to know the details of your system to ensure the safety of our linesmen. We also need to log your connection into our network register.

Once your registered electrician has connected your system, Vector will require the following documents:

- A copy of the Certificate of Compliance (COC), and
- A completed 'Notification of Connection – Distributed Generation (≤10kW)' form

We recommend you keep a copy of these documents for your own records.

Our 'Notification of Connection – Distributed Generation (≤10kW)' form is available:

- on Vector's website: www.vectorelectricity.co.nz
- by phone on (09) 303 0626
- by mail from: Customer Connection Coordinator
Vector Limited
PO Box 99882
Newmarket
Auckland
- by email from: dginfo@vector.co.nz

Change of occupancy

You are responsible for the maintenance of your distributed generation system to the appropriate standards. You are also responsible for notifying any future owners/tenants of the property about the responsibility and obligations of having a distributed generator connected to Vector's network.

Should you sell your property, or someone else moves in, it is important that the new operator of the distributed generator understands the requirements for ensuring a safe and well-maintained electricity connection. The new owner/operator must complete the 'Notification of Connection – Distributed Generation (≤10kW)' form with their amended details.

For further information

When you decide to install distributed generation, you want to do it right. We want you to do it right too. So if you have any queries or you require further information, please call us on (09) 303 0626.

Vector Limited
101 Carlton Gore Road, Newmarket
PO Box 99882, Newmarket
Auckland

General Enquiries: (09) 303 0626
Email: dginfo@vector.co.nz
www.vectorelectricity.co.nz

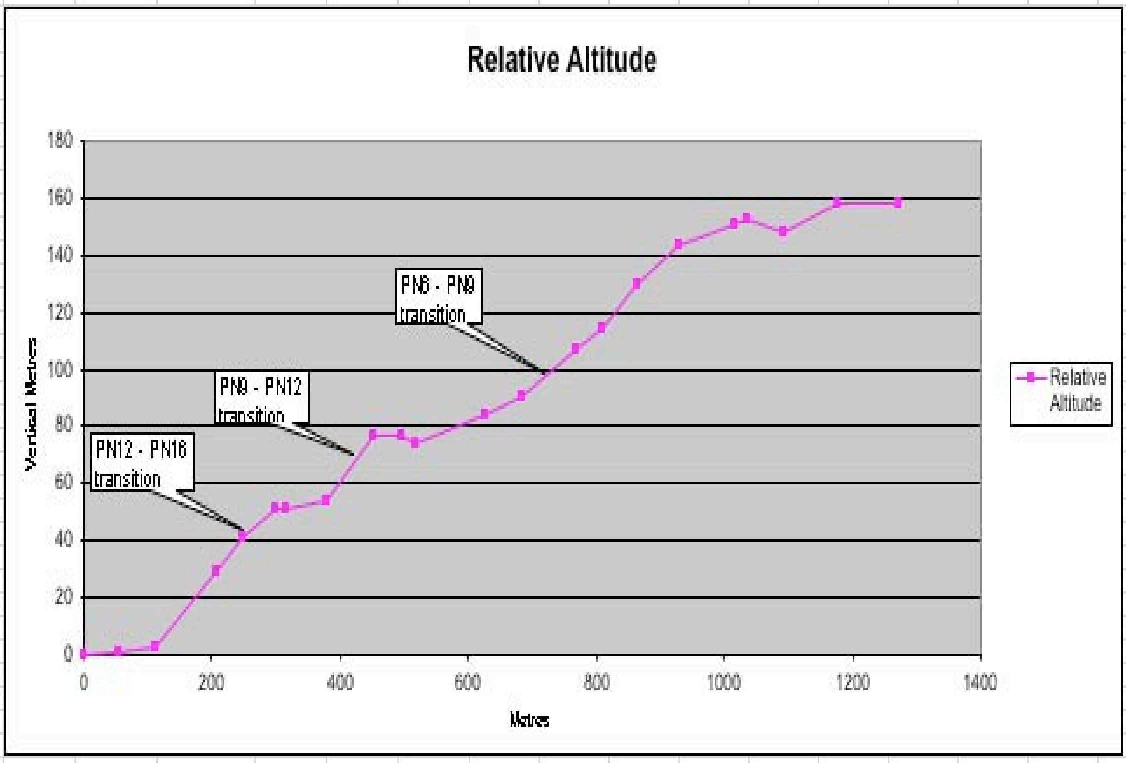
Appendix 3 Pipeline optimisation spreadsheet

The first chart records the survey results and lists distances on the pipeline route where altitude measurements were taken. These measurements were then plotted against the distance to generate a pipeline profile.

Subsequent pages of this appendix contain screen grabs from the online design tool used to calculate the flow resistance of each pipeline section. The head losses are then summed to obtain the total frictional loss.
Although the model is based on a pumped system the analysis is equally valid for water movement due to gravity as the frictional loss in the pipeline is independent of the energy source moving the water. PolyPlex 80 is the brand name used by Iplex for their equivalent MDPE pipeline in Australia.
(Courtesy Iplex Industries)

Pipe Survey
Totara Valley
23/11/05

Actual Reading before 1.09 correction	Distance from Turbine (Metres)	Relative Altitude	
0	0	0	
50	55	1	
100	112	3	
189	208	29	
228	249	41	
275	300	51	
291	317	51	
348	379	54	
414	451	77	
455	498	77	
474	517	74	
575	627	84	
626	682	90	
704	767	107	Top of Cedar Trees
741	808	114	
792	863	130	
852	929	143	
901	1015	151	
949	1034	153	High point before saddle
1002	1092	148	Dip in saddle
1080	1177	158	
1168	1273	158	Top of waterfall



Pipeline profile from turbine (left) to intake (right)

safety data sheets

plumbing | irrigation | stormwater | mining & industrial
water supply | energy & telecom | sewer | trench-less technology

iPLEX Design tools

Totara Valley

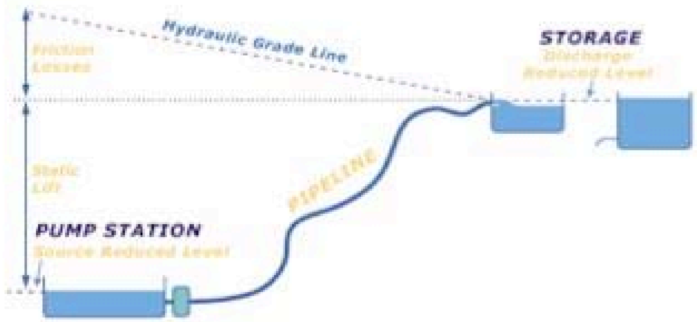
PUMPED PIPELINE

FLOW CALCULATION RESULTS

DATA	RESULTS
POLIplex PE 80B	Static Lift = 160 (m)
63 mm Class PN6.3	Friction Losses = 7.04 (m)
Inlet RL = 0 m	Total Head at Pump = 167.04 (m)
Discharge RL = 160 m	Flow Velocity = 0.79 (m/s)
Pipeline Length = 573 m	
Colebrook White k = 0.01 mm	
Required Flow Rate = 2.0 (l/S)	

Results:

1. View results given for total head at the pump, flow rate and velocity.
2. Check that the pipe class selected is greater than total head on the pipeline. This is normally at the pump but it could be at another location if the pipeline falls below the reduced level at the pump before rising again to the storage. Re-run the program with a higher pipe pressure class if necessary.
3. It is recommended that the design velocity does not exceed 6 m/s. Select a larger pipe and re-run the program if necessary.



ONLINE DESIGN TOOLS:
- Pumped Pipeline
- Pressure Gravity Pipeline
- Non Pressure Gravity Pipeline

PN 6 section of Pipeline

safety data sheets

plumbing | irrigation | stormwater | mining & industrial
water supply | energy & telecom | sewer | trench-less technology

iPLEX Design tools

Totara Valley

PUMPED PIPELINE

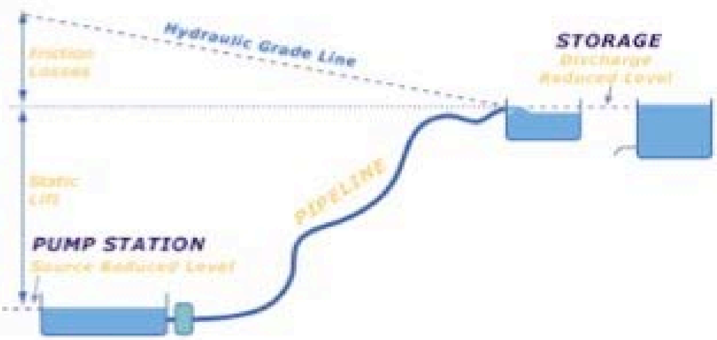
FLOW CALCULATION RESULTS

DATA	RESULTS
POLIplex PE 80B	Static Lift = 160 (m)
63 mm Class PN8	Friction Losses = 3.56 (m)
Inlet RL = 0 m	Total Head at Pump = 163.56 (m)
Discharge RL = 160 m	Flow Velocity = 0.84 (m/s)
Pipeline Length = 250 m	
Colebrook White k = 0.01 mm	
Required Flow Rate = 2.0 (l/S)	

ONLINE DESIGN TOOLS:
- Pumped Pipeline
- Pressure Gravity Pipeline
- Non Pressure Gravity Pipeline

Results:

1. View results given for total head at the pump, flow rate and velocity.
2. Check that the pipe class selected is greater than total head on the pipeline. This is normally at the pump but it could be at another location if the pipeline falls below the reduced level at the pump before rising again to the storage. Re-run the program with a higher pipe pressure class if necessary.
3. It is recommended that the design velocity does not exceed 6 m/s. Select a larger pipe and re-run the program if necessary.



PPN 9 (PN8) pipeline section

safety data sheets

plumbing | irrigation | stormwater | mining & industrial
water supply | energy & telecom | sewer | trench-less technology

iPLEX Design tools

Totara Valley

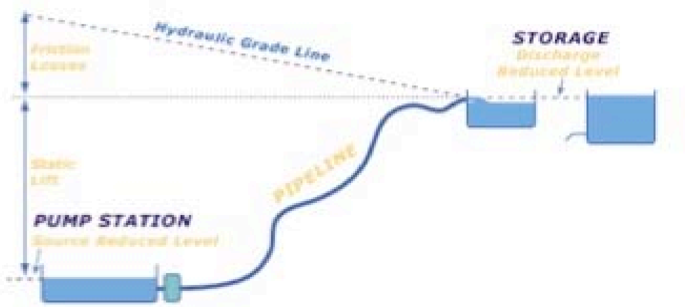
PUMPED PIPELINE

FLOW CALCULATION RESULTS

DATA	RESULTS
POLIplex PE 80B	Static Lift = 160 (m)
63 mm Class PN12.5	Friction Losses = 4.17 (m)
Inlet RL = 0 m	Total Head at Pump = 164.17 (m)
Discharge RL = 160 m	Flow Velocity = 0.98 (m/s)
Pipeline Length = 200 m	
Colebrook White k = 0.01 mm	
Required Flow Rate = 2.0 (l/S)	

Results:

1. View results given for total head at the pump, flow rate and velocity.
2. Check that the pipe class selected is greater than total head on the pipeline. This is normally at the pump but it could be at another location if the pipeline falls below the reduced level at the pump before rising again to the storage. Re-run the program with a higher pipe pressure class if necessary.
3. It is recommended that the design velocity does not exceed 6 m/s. Select a larger pipe and re-run the program if necessary.



ONLINE DESIGN TOOLS:
- Pumped Pipeline
- Pressure Gravity Pipeline
- Non Pressure Gravity Pipeline

PN12 pipeline section

iPLEX Design tools

Totara Valley

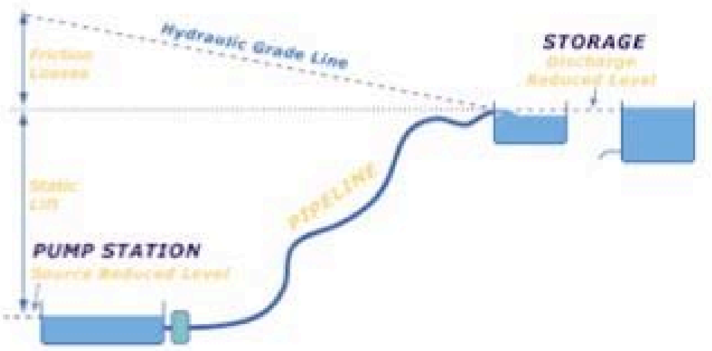
PUMPED PIPELINE

FLOW CALCULATION RESULTS

DATA	RESULTS
POLIplex PE 100	Static Lift = 160 (m)
63 mm Class PN16	Friction Losses = 5.22 (m)
Inlet RL = 0 m	Total Head at Pump = 165.22 (m)
Discharge RL = 160 m	Flow Velocity = 0.98 (m/s)
Pipeline Length = 250 m	
Colebrook White k = 0.01 mm	
Required Flow Rate = 2.0 (l/S)	

Results:

1. View results given for total head at the pump, flow rate and velocity.
2. Check that the pipe class selected is greater than total head on the pipeline. This is normally at the pump but it could be at another location if the pipeline falls below the reduced level at the pump before rising again to the storage. Re-run the program with a higher pipe pressure class if necessary.
3. It is recommended that the design velocity does not exceed 6 m/s. Select a larger pipe and re-run the program if necessary.



ONLINE DESIGN TOOLS:
Pumped Pipeline
Pressure Gravity Pipeline
Non Pressure Gravity Pipeline

PN16 pipeline section

Appendix 4 Equipment and Materials specifications

"Highgear Loft" climbers altimeter was used to make altitude measurements on this project. The readings were compared and found to be similar to those obtained with an analogue altimeter briefly loaned to check readings.

Altimeter Specifications

Altimeter
+ Working range -2,305 to 30,045ft (-702m to 9158m)
+ Current, Accumulated and Maximum altitude in ft or m
+ Altitude resolution 3ft (1m)
+ Graphic altitude trend display
+ Altitude alarm
+ Stores 20 altimeter data readings with altitude, time, and date

Barometer
+ Sea level pressure and absolute pressure displays in both mbar and inHg
+ Resolution 1mbar (0.05inHg)

+ Working range: 300mbar to 1100mbar (8.16inHg to 32.48inHg)
+ 24 hour graphic barometric pressure trend display
+ Barometer/Temp display
+ 6 hour weather forecast feature

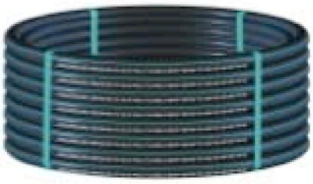
Appendix 5 Polyethylene Pipe specifications

Data taken from data supplied on the Iplex web site.
Iplex are an Australasian company with manufacturing facilities in Palmerston North.
Specifications of the four pipe grades used in this project are included on the data sheet.

GREENLINE

FLEXIBLE MEDIUM DENSITY POLYETHYLENE PIPE

More litres per metre



6 Bar

370 Series

Iplex Pipelines' GREENLINE is a metric pipe made from flexible, PE80B medium density polyethylene (MDPE) to international standards. A popular material for rural water reticulation, MDPE is lightweight, strong and durable.

GREENLINE is a pipe system that has been specifically developed to suit today's modern farming practices. It is a reliable, economical system which maintains a consistent pressure rating across a wide range of sizes.

The GREENLINE system uses the technically superior AGFIT™ compression range of pipe fittings.

FEATURES AND BENEFITS

Efficient GREENLINE transports more litres per metre and has a larger bore size compared to traditional LDPE pipe.

Reliable GREENLINE is a reliable and economical system that maintains a consistent pressure rating across a wide range of sizes. GREENLINE is rated 9 bar in 20mm and 8 bar in 25mm and 32mm diameters.

Flexible GREENLINE is a medium density polyethylene pipe that is light, strong and flexible.

Suitable GREENLINE is suitable for use with in-line bloat dispensing systems, based on testing in accordance with ASTMD 1693 "Environmental Stress Crack Resistance".

Compatible The GREENLINE system is easily connected to existing high density (HDPE) and low density (LDPE) polyethylene pipes as well as PVC and GWI systems, using threaded fittings.

Versatile Greenline, when used in conjunction with our comprehensive and technically superior range of AGFIT™ and Plasson compression pipe fittings, builds a total system. AGFIT™ fittings are easy to assemble – there's no need for special tools or hot water. When correctly assembled, AGFIT™ won't pull apart around troughs and gateways even when kicked or trodden on. AGFIT™ fittings are simple to use and have been put to the test, with years of demanding use in agricultural applications in New Zealand and throughout the world.

Durable GREENLINE is made from tough polyethylene.

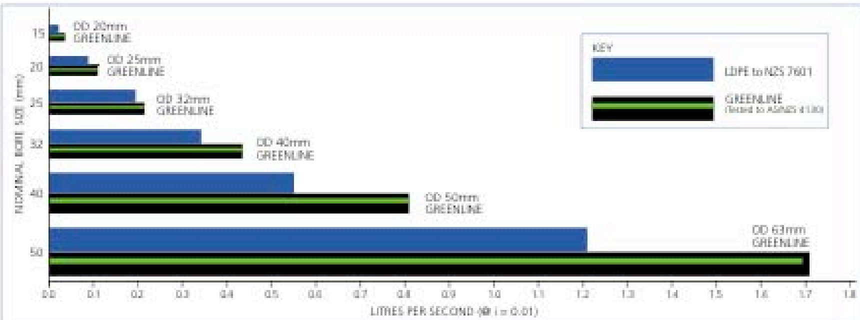
Visible The three permanent green stripes on GREENLINE ensure instant identification.

Economical GREENLINE is available in 3 different coil lengths (50, 100 and 200 metres) to suit a wide range of applications.

Quality GREENLINE is manufactured in New Zealand by Iplex Pipelines using a quality system accredited to ISO 9002:1987.

GREENLINE is tested to AS/NZS 4130:1997 - "PE Pipes for Pressure Applications".

Flow rate comparison



Page 2

FACT SHEET

		Greenline (370 Series)		Redline™ (360 Series)		Blueline (2500 Series)		Blackline (3500 Series)	
		Bar	PSI	Bar	PSI	Bar	PSI	Bar	PSI
Pressure Rating *	20	9	131	12.5	182	12.5	182	✗	✗
	25	8	116	12.5	182	12.5	182	✗	✗
	32	8	116	9	131	12.5	182	16	233
	40	6.3	91	9	131	12.5	182	16	233
	50	6.3	91	9	131	12.5	182	16	233
	63	6.3	91	9	131	12.5	182	16	233
Mean Internal Diameter	20	16.0		16.6		16.1		✗	
	25	21.0		20.7		20.1		✗	
	32	26.9		27.8		25.9		25.9	
	40	35.0		34.8		32.3		32.3	
	50	43.8		43.5		40.5		40.5	
	63	55.2		54.8		51.0		51.0	
Standard Coil Sizes (M)	25	✗		✗		✓		✗	
	50	✓		✓		✓		✗	
	100	✓		✓		✓		✓	
	200	✓		✓		✗		✗	
	Bloat resistant	✓		✓		✓		✓	
Fitting Compatibility	AgFit	✓		✓ in diameter 32mm and over		✗		✗	
	Plasson	✓		✓		✓		✓	
	12v Electrofusion	✓		✓		✓		✗	
Pipe Material	PE80B (MDPE)	✓		✓		✓			
	PE100 (HPPE)							✓	

*Maximum operating pressure at 20°C

Technical Specifications

OPERATING TEMPERATURE

–10°C to + 60°C*

*Pressure derating must be applied for operating temperatures above 20°C.

MINIMUM COLD BENDING RADII (M)

(=22 x OD) PIPE OD (mm)	20°C (m)	0°C (m)
20	0.44	1.0
25	0.55	1.2
32	0.71	1.6
40	0.88	2.0
50	1.10	2.5
63	1.39	3.2

Mole ploughing installation

These pipes can be installed by the Mole Plough method providing that the mole plough is specifically designed and maintained for this application and will not subject the pipe to stretching, scoring or any other damage during installation.

Pipe installation

These pipes should be laid at a sufficient depth to protect them from damage by normal agricultural/horticultural cultivation or other operations. It makes good sense to record the location of buried pipes so they can be located again as needed.

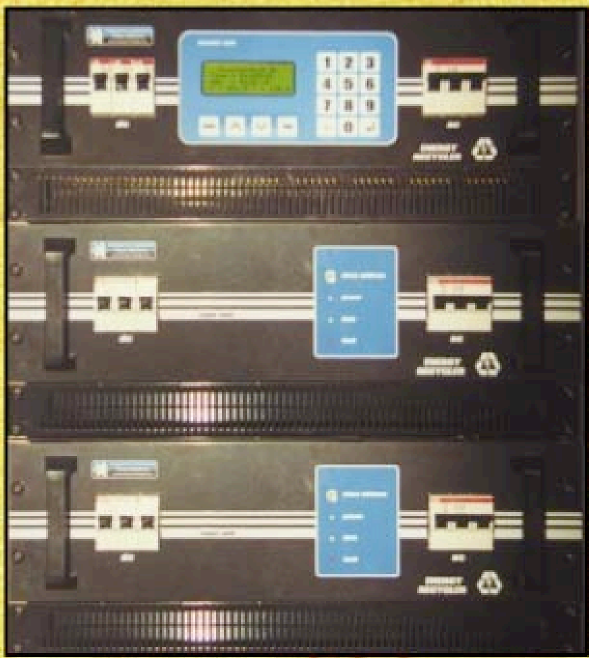
These pipes are not suitable for use:*

1 As a conductor used for earthing electrical appliances.
2 In all fire rated applications.
3 For continuous service above 20°C internal or external temperature, where provision for pressure derating appropriate to the temperature has not been made.
NOTE: Iplex Pipelines' strongly recommend that these systems be buried in service to give protection from high climatic temperatures. High climatic temperatures may reduce the pipe's pressure rating.
* Suitability for conveying a wide range of chemicals is tabulated in the Iplex Pipelines' POLIPLEX Polyethylene Pipe Design Textbook and also in our publication, "A Guide to Chemical Resistance of Thermoplastics and Elastomeric Materials".

Appendix 6 Energy Recyclers Inverter

The Inverter discharges the battery and converts this energy into 230 volts alternating current suitable to feed energy into the grid. Simultaneously the turbine charges the battery. The inverter automatically adjusts the discharge rate to maintain system equilibrium.
The potential for expansion of inverter capacity is considerable; slave modules can be added to the base unit increase capacity up to 100kW. The Energy recyclers inverter is therefore suited to a wide range of turbine power outputs.

Energy Recyclers Ltd.
Battery Discharger



An 18kW Energy Recycler Battery Discharger

The Energy Recyclers Battery Discharger is a controllable load for discharge testing batteries. The product is a DC-AC inverter specifically designed to allow DC energy to be effectively fed back into the AC utility power grid. This eliminates the problems of heat generated with conventional resistive loads and will create a credit with your power utility by spinning your power meter backwards!

- Microprocessor Control
- Lightwieght, Compact & Portable
- High Efficiency - 'Heatless' Load
- Configurable for Battery Voltages/Current
- Cost Effective

The battery discharger comes in an industry standard 19 inch 3U rack case with a user interface being provided by a keypad and a LCD display. The advanced microprocessor control allows the user to pre-set parameters for discharge current, maximum discharge time, maximum discharge Ahr and minimum discharge voltage. These parameters are used to control the discharge test allowing a 'set then forget' operation.

During the discharge test period the LCD display shows battery voltage, discharge current, elapsed time and accumulated Ahrs. This information is also available in RS-232 format to allow computer logging of the test progress.

The battery dischargers are available as master units with keypad and LCD display (2kW, 4kW & 6kW) or as 6kW slave units. Slave units can be added to a master unit to allow any discharge power level up to 100kW.

Slaves can be connected to a master unit in either a parallel fashion to achieve a higher discharge current or in a series fashion to facilitate connection to higher battery voltages.

Selection Chart

	2kW Master	4kW Master	6kW Master	6kW Slave
24 VDC input (18 – 29 V)	60 Amp ER1500/24-M	120 Amp ER3000/24-M	180 Amp ER4500/24-M	180 Amp ER4500/24-S
48 VDC input (36 – 57 V)	40 Amp ER2000/48-M	80 Amp ER4000/48-M	120 Amp ER6000/48-M	120 Amp ER6000/48-S
110 VDC input (82 – 131 V)	20 Amp ER2000/110-M	40 Amp ER4000/110-M	60 Amp ER6000/110-M	60 Amp ER6000/110-S
Weight	17kg	23kg	29kg	29kg
Mains Power	1 – Phase	2 – Phase	3 – Phase	3 – Phase

Specifications

Electrical:
AC Mains Voltage: 220 / 230 / 240V ±20% (specify when ordering)
AC Mains Frequency: 50 / 60 Hz ±10% (specify when ordering)
Efficiency: 90% typ.
DC Input Voltage Ripple: <1%
AC Current Draw (supply): Sinusoidal <5% THD, to IEC1000-3-2, IEC555, EN61000-3-2, JEAG9701
EMI/RFI: to CISPR22 / EN60522 level A
Safety: to IEC950, EN60950, AS/NZS3260
Isolation: AC Mains to case 3500 VAC 1 min.
DC to case 1kV (with DC bypass capacitor removed)

Accuracy:
Discharge Current: ±2.5% of full scale
DC Voltage/Current monitoring: ±1.0% of full scale
AC Voltage monitoring: ±2.0% of full scale
AC Frequency Monitoring: ±1.0% of full scale
Ampere-Hour monitoring: ±2.0% of reading
Elapsed Time: ±1 second

Physical:
Size: 438W x 134H x 500D (mm)
Ambient Humidity: 0-95% RH non-condensing
Ambient Temperature: -10˚C to +40˚C fan cooled
Orientation: Normal vertical 19" rack mount
Accessories: 20A Phoenix AC connector
175A Anderson DC connector

Note: specifications may change

Other Applications & Products

The Energy Recycler product is available in other formats for use as an electronic soak test load or for grid inter-tied photovoltaic renewable energy systems. Energy Recyclers Ltd. also build a comprehensive battery monitor unit, which complements the battery discharger for discharge testing.

Energy Recyclers Ltd.

PO Box 19-501
Auckland 7
New Zealand

Phone +64 9 820 0304
www.EnergyRecyclers.com
Email info@EnergyRecyclers.com

Appendix 7 Eco Innovations Pelton Turbine

Specifications:

The complete Pelton turbine is available in 12/24/48 volt models and is designed and built for your site. These turbines extract energy from flowing water. If used in combination with a battery bank and inverter, these units can supply all the electrical requirements of an energy efficient home. Comes with digital current meter. Head required: 5 - 130m, flow required: 0.25 - 8 L/s, power output: 1000 Watts max (2 jet version).

Courtesy Eco Innovations

Appendix 8 Trace (Xantrex) C-40 specifications

Courtesy of the manufacturer Xantrex Corporation

The Trace C-40 load controller is set up in the "diversion mode" for this project. In this mode the unit switches a power source between two loads. Switching is dependent on a threshold voltage derived from the applied source voltage.
In this project the power source is derived from the turbine, the batteries create the default load and the alternative load is the "dump load".
A full explanation is provided in the operation manual, available on the Xantrex corporation web site.

Trace C40 specifications taken from installation manual.
interested readers can download further details on the Trace C-40 controller at www.xantrex.com

Electrical Specifications

The following lists the electrical specifications for the C-Series controllers Models C35, C40, and C60.

Table A-1 Electrical Specifications

Model	C35		C40			C60	
Voltage Configuration	12 Vdc	24 Vdc	12 Vdc	24 Vdc	48 Vdc	12 Vdc	24 Vdc
Maximum PV Array Open Circuit Voltage	55 Vdc	55 Vdc	125 Vdc	125 Vdc	125 Vdc	55 Vdc	55 Vdc
Charging Load Current	35 amps DC continuous		40 amps DC continuous			60 amps DC continuous	
Recommended Breaker Size with recommended Wire Size in Conduit	60 amps DC #6 AWG		60 amps DC #6 AWG			60 amps DC (100% continuous duty cycle), #6 AWG (90 ° C rated)	
Maximum Short Circuit Current	85 amps intermittently		85 amps intermittently			85 amps intermittently	
Maximum Voltage Drop	0.30 volts - charge control mode						
Total Current Consumption	While operating - 15 mA (typical), at idle - 3 mA (tare)						
Charger Regulation Method	Solid state, 3-stage (bulk, absorption and float) Pulse Width Modulation (PWM)						
Charging Control Settings:							
Lead Acid Battery	12 Volt System: Float 12.5 - 14.5 Vdc Bulk 13.0 - 15.0 Vdc EQ = +1 above Bulk		24 Volt System: Float 25.0 - 29.0 Vdc Bulk 26.0 - 30.0 Vdc EQ = +2 above Bulk			48 Volt System: Float 50.0 - 58.0 Vdc Bulk 52.0 - 60.0 Vdc EQ = +4 above Bulk	
NiCad battery	12 Volt System: Float 14.5 - 16.5 Vdc Bulk 15.0 - 17.0 Vdc EQ = not recommended		24 Volt System: Float 29.0 - 33.0 Vdc Bulk 30.0 - 34.0 Vdc EQ = not recommended			48 Volt System: Float 58.0 - 66.0 Vdc Bulk 60.0 - 68.0 Vdc EQ = not recommended	

Appendix 9 Hoppecke battery specifications

Battery specifications, courtesy Eco Innovations.
Eight 6 volt “Hoppecke” batteries were wired in series to form a 48 volt battery. This voltage was necessary to ensure compatibility with the Inverter and turbine.

Hoppecke USV-1106

These deep cycle batteries are a cost effective smaller sized battery that is easily handled.
They are 6v and weigh 28 kg each.
Specification:
L/W/H 285mm/178mm/285mm
20 hr rate = 120 amp hours
10 hr rate = 105 amp hours

Appendix 10 Financial Analysis Tool

Instructions for use

A spreadsheet-modeling tool was developed to facilitate the analysis of numerous project scenarios and assess the effects of cost variations on the long-term financial performance of these projects. A copy of the modeling tool is included on the CD attached to this document. The modeling tool is divided into two sheets. The first sheet is entitled “Input Sheet” and requires the user to enter the financial attributes of the project.
The spreadsheet sums all of the entered costs and presents the user with a total capital cost of the project at the bottom of the sheet.

How to enter financial values

Values are to be entered into the yellow and orange cells and results are displayed in the green cells.

The Input Sheet caters for several scenarios

1) If a project does not incur some of the itemized costs then the appropriate cells can be left blank.
2) If a breakdown of the pipeline costs is not required, the total pipeline cost can simply be entered in the “other” cell in the cost/m column. This cell is coloured orange.
3) If a breakdown of labour costs is not required the total labour cost can be entered in the “other Works” cell. This cell is coloured orange
4) Finally any additional items purchased but not categorized can be entered in the “other materials” cell. This cell is coloured orange

In addition the spreadsheet model also performs a Discounted Cash flow Analysis(DCF) on the project financial data and derives the Net Present value(NPV) of the project. Subsequently the Internal Rate of Return(IRR) of the project over a 10 year project life can also be computed. Greenhouse gas emissions avoided can also be derived from the input data. To derive these values some additional information is required. These values are entered in “Part B” of the Input Sheet.

To summarise, the required parameters in the order that they appear.

1) Total estimated electricity output per annum for the project. This should be an averaged value if production is expected to vary significantly each year.
2) The Sale price of electricity generated in the first year of production
3) Annual expected inflation rate in % format
4) Expected electricity price increases in addition to inflation in % format
5) Discount rate, this is the required return on the invested funds in % format
6) Annual maintenance cost, this is automatically inflation adjusted

7) Annual Resource Consent charges, this is automatically inflation adjusted
8) Unscheduled maintenance costs represent the estimated annual allowance to cover the repair of system breakdowns
9) Carbon intensity represents the carbon intensity of the grid power that the system is offsetting. Presently in New Zealand this equates to 0.15 kg/kWh

This concludes entering all of the data that is required to complete the analysis. The user should now click on the "Results tab' at the bottom of the screen to examine the project results.

A snapshot of the input sheet is depicted in Table A.

Micro-hydro cost model

Input Sheet

Part A - Capital cost Analysis

Enter costs in Yellow cells below

Calculated values are displayed in green cells

Material costs

Turbine cost	$1,200.00
Shed, Shelter	$355.00
Total cost Pipe & fittings (itemised in gold cells below) — Total pipe costs are here >	$3,255.44

Enter itemised costs in Yellow cells below, total pipe and battery costs will appear in appropriate green cell

Breakdown of Pipe costs — Grade	Metres	cost/m	
PN6	600	$2.48	$1,488.00
PN9	250	$3.17	$792.50
PN12	200	$3.36	$672.00
PN16	0	$6.86	$0.00
Fittings(cost each)	11	$27.54	$302.94
Other	1	$0.00	$0.00

	Number	Cost each		
Batteries (If required)	0	$0.00	Total battery costs are here >	$0.00
Inverter				$3,999.00
Voltage Regulator (If not supplied with turbine)				$250.00
Control panel, meters monitoring equipment				$200.00
Electrical fuses, wiring and fittings				$300.00
Diversion load				$200.00
Pipe and other materials for tailrace construction				$120.00
Other Materials				$0.00

Administration & Consent Costs

Resource consent charges	$1,589.00
Connection charges	$200.00

Labour costs

	Hours	Rate/hour		
Electrician, grid connection	6	$ 70.00	< Enter labour costs here	$420.00
Non specialist labour	70	$ 20.00		$1,400.00
Consultancy Fees				$0.00
Other Works				$0.00

Total capital cost **$13,488.44**

Part B - Enter values for cashflow analysis

Enter total kWh generated per annum	8400	Kwh
Enter electricity sale price cents/kWh	23.40	cents
Enter annual inflation rate %	2.5	%
Enter annual electricity price increase (% in addition to inflation rate)	10.0	%
Enter discount rate % (required investment return)	9.5	%
Annual maintenance costs	$400.00	
Annual ongoing Resource consent fees	$200.00	
Unscheduled maintenance allowance	$250.00	
Carbon intensity of existing grid supply in kg CO_2/kWh generated	0.15	Kg/kWh

Table A – Results screen showing typical values

Explanation of the "Results" screen

The "Summary Results" screen displays the parameters most investors will seek to evaluate the feasibility of the project.
Each parameter is defined in the order that they appear

1) Capital cost is the total up front cost to purchase and install the system to the operational milestone.
2) The Net present value of the system is the inflation adjusted net value of the system to the owner after all of the costs and all of the income is accounted for. A positive value represents an additional return to the owner on top of the required rate of return (discount rate). A negative value represents a loss and implies the rate of return is less than what is required.
3) The expected value of electricity sold (or cost avoided) is presented for each year over a 10 year period with an allowance for the entered inflation rate and expected electricity price rises.
4) The total electricity generated over the 10 year project life is presented
5) The average unit cost to generate each kWh of electricity is presented
6) The equivalent weight of carbon dioxide gas emissions avoided is derived from the total output and the energy intensity of the local grid.
7) Finally clicking on the "IRR" macro button calculates the Internal Rate of Return for the project. This is the rate of return that results in a net present value of zero and represents the overall percentage return on the initial capital investment.

A discounted cash flow analysis is also presented below the summary results should further analysis of each years financial performance be necessary.

A snapshot of the Results screen is shown in Table B.

Micro-hydro cost model

Summary Results

Capital cost	$ 13,488.44	
Net present value of system	$ (0.00)	

Value of electricity generated each year (in installation year dollar value)

Installation Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
$ 1,965.60	$ 1,974.63	$ 1,983.70	$ 1,992.81	$ 2,001.96	$ 2,011.15	$ 2,020.39	$ 2,029.67	$ 2,038.99	$ 2,048.36

Total kWh output over project life	84,000	kWh
Average unit cost of electricity generated	$ 0.24	cents/kWh
Greenhouse gas emissions avoided over project life	12,600	kg
Internal rate of return of project (Click to calculate IRR)	9.50	%

Discounted cashflow analysis

	Installation Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Income										
Value of electricity generated	$ 1,965.60	$ 2,162.16	$ 2,378.38	$ 2,616.21	$ 2,877.83	$ 3,165.62	$ 3,482.18	$ 3,830.40	$ 4,213.44	$ 4,634.78
Discount factor	0.00	1.09	1.20	1.31	1.44	1.57	1.72	1.89	2.07	2.26
Present value per kWh generated	$ 0.23	$ 0.26	$ 0.28	$ 0.31	$ 0.34	$ 0.38	$ 0.41	$ 0.46	$ 0.50	$ 0.55
Present value of electricity	$ 1,965.60	$ 1,974.63	$ 1,983.70	$ 1,992.81	$ 2,001.96	$ 2,011.15	$ 2,020.39	$ 2,029.67	$ 2,038.99	$ 2,048.36
Expenses										
Initial capital investment	$ 13,488.44									
maintenace	$ -	$ 400.00	$ 410.00	$ 420.25	$ 430.76	$ 441.53	$ 452.56	$ 463.88	$ 475.47	$ 487.36
resource consent fees	$ -	$ 200.00	$ 220.00	$ 242.00	$ 266.20	$ 292.82	$ 322.10	$ 354.31	$ 389.74	$ 428.72
unscheduled maintenance	$ 250.00	$ 250.00	$ 275.00	$ 302.50	$ 332.75	$ 366.03	$ 402.63	$ 442.89	$ 487.18	$ 535.90
total expenses	$ 13,738.44	$ 850.00	$ 905.00	$ 964.75	$ 1,029.71	$ 1,100.37	$ 1,177.29	$ 1,261.08	$ 1,352.40	$ 1,451.98
Discount factor	0.00	1.09	1.20	1.31	1.44	1.57	1.72	1.89	2.07	2.26
Present value of expenses	$ 13,738.44	$ 776.28	$ 754.82	$ 734.86	$ 716.31	$ 699.08	$ 683.08	$ 668.23	$ 654.46	$ 641.71
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Annual present value of project	$ (11,772.84)	$ 1,198.35	$ 1,228.88	$ 1,257.94	$ 1,285.65	$ 1,312.08	$ 1,337.32	$ 1,361.44	$ 1,384.53	$ 1,406.65
Net present value of system	$ (0.00)	Over 10 year project life								

Table B – Results Sheet showing typical values

The third worksheet on the model is the “cost sheet”. This is where most of the formulas reside and calculations are performed. This sheet has been made visible for review and assessment purposes.
Finally the spreadsheet is locked, however no password is required to unlock it and modify or examine the cell contents.

Appendix 11 Contents of attached CD

1. **Copy of this Thesis**
2. **Working copy of spreadsheet based financial modeling tool**
3. **Photo gallery of images taken during construction of the project**
4. **PowerPoint presentation on project**