ENERGY ANALYSIS OF MINI HYDRO SCHEMES USING PLANT PERFORMANCE DATA

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Degree of Master of Engineeringin EnergyTechnology

Department of Mechanical Engineering

University of Moratuwa

Sri Lanka

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Thesis submitted in partial fulfillment of the requirements for the degree
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DECLARATION

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ABSTRACT

In this research project, characteristics of mini hydro power schemes which affect to the performance of the scheme were analyzed. The main objective of the project was to develop an analytical criterion to estimate the variations of the energy associated with small hydropower schemes which plays a major role in feasibility of the mini hydro scheme while fulfilling the other objectives of defining site specific efficiency factors associated with each mini hydro power scheme. For the present model of forecasting annual energy variations, the factors being used for computing anticipated energy losses in and during the sections of weir entrance, head race canal, forebay tank, penstock line, hydraulic turbines and electricity generator are not site-specific and technology specific. Therefore an experimental approach was used in combination with statistical data analysis to develop a relationship between stream flows with scheme characteristics. Electrical power generation, rainfall of the nearby meteorological data measuring stations, plant maintenance records were analyzed and several catchment runoff calculation methods were studied. Four consecutive operational mini hydro schemes were selected and relationships among their operational characteristics were studied during the analysis.

The results of the study show that performance data of adjacent operational power schemes can be used to predict energy potential of a downstream scheme which is situated within 5 km distance from the operational plant. By the proposed model energy potential of a selected mini hydro scheme can be estimated very accurately for the first five months of the year with a slight deviation varies in the range 2% to 11%. But this model cannot be recommended to estimate energy potentials of upstream to the considered operational scheme. This can be used as a simple hydrological resource as this model can forecast energy potentials without using current hydrological data as it associates only performance data of mini hydro power plants.

Key words: mini hydro power scheme, flow duration curve, performance characteristics, turbine efficiency

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My sincere thanks also goes to Mr S. Kithsiri, Director (Renewable Energy), SLSEA, who facilitated me in data collection, Mr. Sunith Fernando (Energy Consultant, Resource Management Associates), Ms. N. Kavirathna, GIS specialist, SLSEA, for her support in hydrological data collection and GIS modeling and Mr. P. V. S. Shantha, Assistant Director (Environmental Impact Assessments), CEA, for his support in data acquisition.

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LIST OF ABBREVIATIONS

Abbreviation	Description
PPP	Private Power Producers
NRE	New Renewable Energy
SLSEA	Sri Lanka Sustainable Energy Authority
MHPP	Mini Hydro Power Project
GIS	Geographical Information System
MH	Mini Hydro

1. INTRODUCTION

1.1. Background

The installed electricity generation capacity in Sri Lanka reached 3,443 MW in 2014 while the maximum demand reached was 2,152 MW. Gross electricity generation of Sri Lanka was 12,849 GWh in 2014 and 70% of gross generation was supplied by state owned power plants having 2,824 MW of installed capacities while 30% was supplied by private power producers (PPP) having 1,220 MW installed capacities[1]. The share of New Renewable Energy (NRE) in the generation mix was 9.8% in 2014. Figure 1.1 shows the electrical energy mix of Sri Lanka in 2014. Sri Lanka defines mini hydropower plants as hydropower plants below 10 MW of installed capacity. Currently, 172 mini hydropower plants are being operated in Sri Lanka contributing 342 MW to the national electricity grid, entirely owned by PPPs. Small hydropower sector is the most dominant new renewable energy sector which contributes a share of 74.1% in NRE generation alone, and 7.3% to the total generation of Sri Lanka.

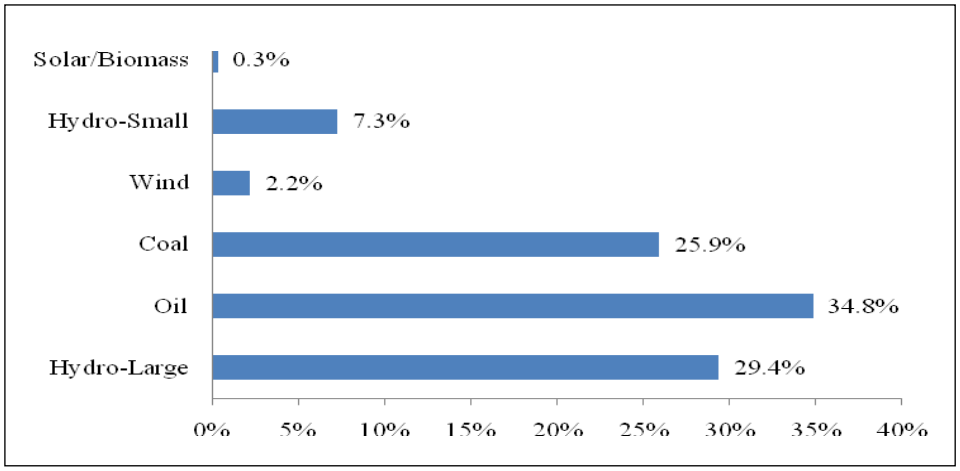

Figure 1.1: Electricity generation in Sri Lanka[2]

At present Sri Lanka has the challenge of developing unexploited small hydro potential of 585 MW, which is a significant amount compared to the already developed mini hydro power schemes, from the limited number of economically feasible potential sites as identified and gazetted by the Sri Lanka Sustainable Energy

Authority (SEA) as shown in figure 1.2. According to SEA, the total economically feasible small hydropower potential in Sri Lanka is 873 MW[3]. The cumulative capacity additions from NRE resources from 1996 reflects the fact that capacity additions from NRE plants including small hydropower plants accelerated steadily since 2007 with the establishment of SEA in 2007, which resulted in a stepped up production of small hydro power in the consecutive years. In this case developing rest of hydro resources in a sustainable manner is a major expectation.

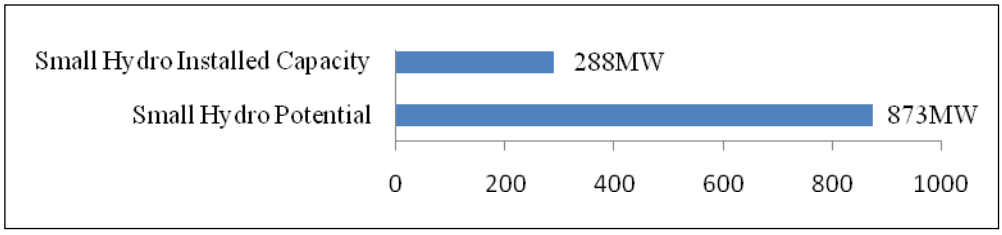

Figure 1.2: Small hydro power capacities in Sri Lanka [2]

Further in terms of pre feasibility evaluation of mini hydro power schemes, improvement of accuracies of predicted energy generations estimates realistic results for evaluating financial feasibility of the schemes which can save lots of financial resources of private power producers and optimize the hydro resource utilization. In addition to the national importance of the results of this study, it can further be used in developing energy forecasting models for similar catchments of other regions and countries. Therefore at the moment there is a need to use a very accurate energy forecasting model to evaluate the rest of potential mini hydro schemes using available resource base of Sri Lanka Sustainable Energy Authority, to prevent the possible loss of energy due to inaccuracies of the pre-feasibility studies.

1.2. Motivation

As a country which is targeting for achieving the goal of 20% electricity generation by new renewable energies by 2020[4], about 585MW is still to be explored from the limited number of potential sites for mini hydro power developing. In achieving this goal emphasizing the need of utilizing the energy resource in an optimum manner, a

proper system for assessing hydro energy potentials of selected hydro resources is being mandated to evaluate the performance of current mini hydro power plants with a view of implementation of guide lines in hydro resource allocation procedure. In addition to this, results obtained from performance testing of mini hydro power plants provides a strategic input for pre-feasibility study and design of mini hydro power plants. In evaluation of pre-feasibility study reports these results can be used to confirm the accuracy and authenticity of the claimed potential new project sites in resource allocation process. In this study, annual energy generation potential under the expected plant capacity factor of 40% is considered because the same is considered for mini hydro tariff setting.

Analysis of performance of mini hydro power schemes is a very important phenomenon in evaluation of pre-feasibility study reports of mini hydro power schemes as it gives an overview of energy yields that can be predicted from those schemes. The performance of a mini hydro power scheme is basically depends on associated hydrological parameters, topography and technical parameters of the scheme. Energy extracted by turbo machineries in mini hydro power plants varies with the associated river flow. Modelling of energy potential variations throughout the year will help to estimate the expected energy yield per year for a selected catchment accurately and make decisions regarding hydro resource allocation for mini hydropower development. In Sri Lanka, it is hard to find any research which has been conducted to model the energy potential associated with river flows of different catchments.

Currently it has been noted that the actual energy yields of the selected catchments are different from the same calculated according to the current model used in resource allocation process. Especially having allocated the hydro resource for lower energy potentials will not only reduce the profitability of the project and also discourages the hydro power developers, and then reduces the total energy generation from non conventional renewable energy resources. The main parameter which influences the energy potential is the runoff of the catchment other than the gross head of the project site. If a mathematical model can be developed to simulate

the variations of river flow and the runoff of the catchment using the performance data of operational adjacent power plants which are operated in same river, the difference between actual energy potential and the modelled can be minimized.

Over the past years since 2010, a model has been used in order to study the variation of rain fall and runoff associated with small catchments suitable for mini hydro power projects and to calculate annual energy yields anticipated in the future. The main parameters used in this model are gross head of the selected mini hydro power development site and flow of the river.

Figure 1.3 shows the comparison of forecasted annual energy generation of commissioned mini hydro power plants with their actual energy outputs. According to that difference in actual versus forecasted accounts for about 11 % of total forecasted annual energy generation.

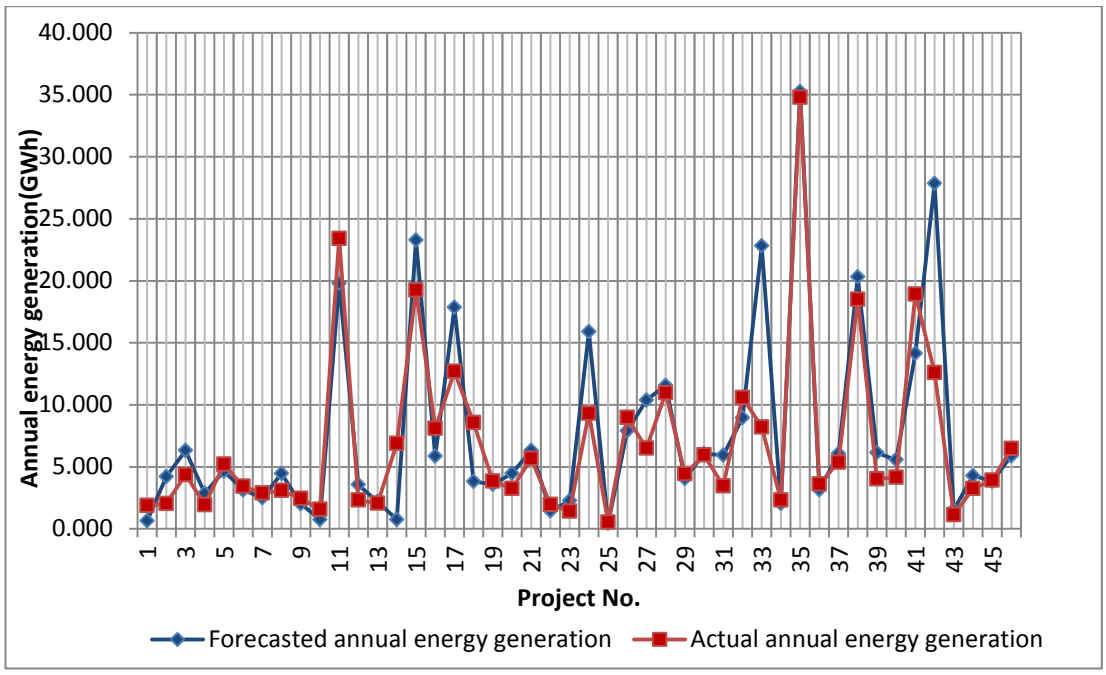

Figure 1.3: Forecasted Vs actual annual energy generations of mini hydro power plants in Sri Lanka

The model used to forecast annual energy generations mostly has focused on finding flow duration data by using a common runoff factor for all catchments with the use of past actual rain fall data of 1996-2014 period. However, the accuracy of this

runoff factor has not been proven or characterized methodically in Sri Lanka.

The aim of this study is to scrutinize the variation of expected energy generation by using performance data of commissioned mini hydro power plants for selected catchments.

1.3. Aim and objectives of the research

The aim of this research project is to help small hydro power developers and the regulatory body to estimate annual energy potentials accurately and consequently evaluate the feasibility of small hydro power projects. The objectives of the research are given below.

- Estimate variations of energy yields, using actual performance data of the adjacent mini hydro power plants.
- Assess the deviation of actual annual energy generations of catchments with forecasted annual energy generations based on the current model.

Then to develop a very accurate predictive model which minimizes the deviation between forecasted and actual annual energy generations. This may minimize the major drawback of using common catchment characteristics for every catchment practised by the current model.

2. LITERATURE REVIEW

2.1. Performance of a mini hydro power scheme

Actual annual energy generation of mini hydro power scheme depend on its performance of operation and it can be tested based on following two criteria.

1. Based on technical criteria
2. Based on sustainability criteria

In these studies, methods of testing for those two criteria are discussed. In technical criteria, energy efficiency of each part of the MHPP is subjected for the test. Under this criteria, energy loss at each component of the MHPP is measured by using effective measuring techniques with relevant measuring equipment at the components of head race canal, forebay tank, penstock, turbine and generator. Energy lost expected beyond the power house, i.e. at transmission and distribution sections are neglected in the study.

Under the sustainability criteria, sustainability of the project considering the areas of environmental, sociological and economic are evaluated using available techniques like lifecycle assessments.

2.2. Basic definitions regarding energy potential of a mini hydro power plant

In the context of mini hydro power plants, they are different from large scale hydro power plants by the scale of power generation and the impact to the environment. The terminology used for naming hydropower schemes defer from country to country as in Sri Lanka 20kW to 10MW is considered as “Mini Hydro” schemes and above 10MW is recognized as “Major Hydro” while less than 1kW to 20kW is considered as “Small Hydro” and less than 1kW is considered as “Pico Hydro” schemes [5].

Hydro power schemes basically can be divided into major two categories [6].

1. Run off river schemes
2. Water storage schemes

In run off river schemes water available in the natural stream is used for power generation without a use of water storage facility as the term “run off river” implies. As this type of hydro power plants use the water available in the stream at the same time the power generated is subjected to the fluctuations of the river flow corresponding to the variations of the associated hydrological cycle. Therefore these schemes are well suited for supply the electrical energy to the national grid as practised in Sri Lanka. On the other hand these schemes are only suited to supply electricity to isolated units such as rural villages, factories etc. only if the minimum stream flow is sufficient to generate power in a capacity greater than the maximum demand of aforementioned. Figure 2.1 shows basic components of a mini hydro power plant.

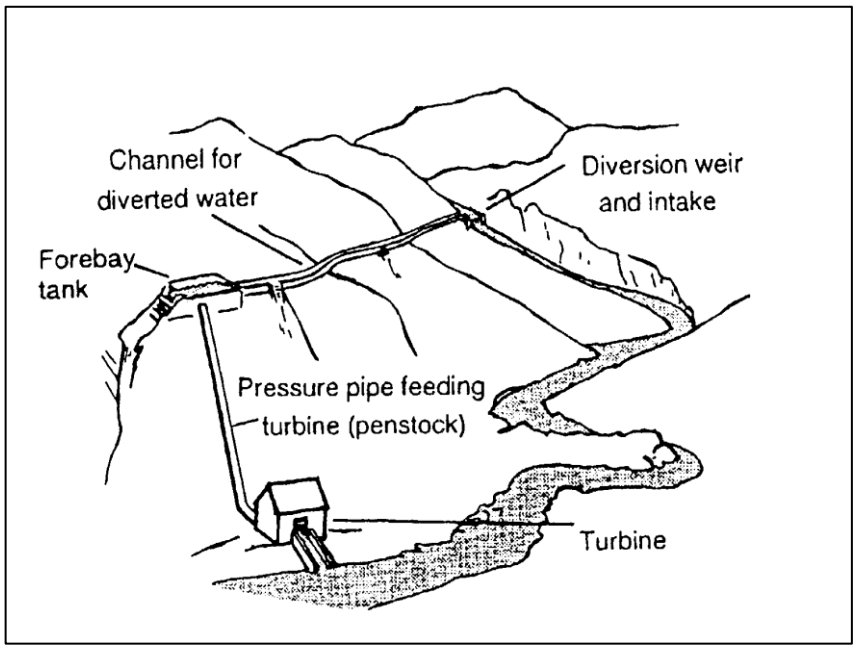

Figure 2.1: Schematic of a mini hydro scheme [7]

In this study performance of only small hydropower schemes is considered.

Mini hydro power plant

All mini hydro power schemes of Sri Lanka are included to the category of run off the river type. There are five major components which should be focussed in evaluating the technical performance of a mini hydro power plant. They are head

race canal, forebay tank, penstock, hydraulic turbine and generator. The theory of hydro power generation from a mini hydro power scheme is based on the potential energy associated with water flow which corresponds to the differential net head [8].

As mentioned above the hydroelectricity conversion is an energy conversion process where the energy associated at the water intake point of the diversion is converted in to first the mechanical energy of the turbine and then to the electrical energy of the generator with possible energy losses through the canal, penstock and the turbine due to friction and in the generator due to eddy current losses, hysteresis losses, copper losses and mechanical losses at the generator.

Head (H) of a water flow can be considered as the total energy associated with a unit mass of water.

$$H = Z + \frac{P}{\rho g} + \frac{V^2}{2g} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.1$$

Where; Z is elevation above a datum plane, P is static pressure of the flow, V is velocity of the flow, ρ is density of the flow and g is gravitational acceleration. For the calculations it is considered that the velocity of the water flow at the datum plane is negligible and considered as almost zero.

Turbine efficiency

Hydro turbines convert hydraulic energy available in the water flow into mechanical of the turbine rotors. Depending on the way how turbine runners act on the rotors, hydro turbines are divided into two categories [8].

1. Impulse turbines – a free jet at atmospheric pressure
2. Reaction turbines – a pressurized flow

Table 2.1 shows different turbine types with their range of applications which is based on the concept of operating with minimum losses of energy by maximizing the efficiency.

Table 2.1: Application range of turbines

Hydraulic Turbines		H (m)	Q (m^3/s)	P (kW)	N_s (r.p.m.) (kW,m)
Reaction	Bulb	2-10	3-40	100-2500	200-450
	Kaplan and propeller - axial flow	2-20	3-50	50-5000	250-700
	Francis with high specific speed - diagonal flow	10-40	0.7-10	100-5000	100-250
	Francis with low specific speed - radial flow	40-200	1-20	500-15000	30-100
Impulse	Pelton	60-1000	0.2-5	200-15000	<30
	Turgo	30-200		100-6000	
	Cross-flow	2-50	0.01-0.12	2-15	

Source: (Based on several manufacturers data) [8]

Technical performance of hydraulic turbines is basically depend on the flow rate and net head of the scheme, and can be represented by the term "efficiency".

Efficiency of the turbine, η is defined by the ratio of power delivered to the shaft to the power taken from the flow [8], Hence

$$\eta = \frac{\text{power delivered to the shaft}}{\text{power taken from the flow}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.2$$

$$= \frac{P}{H_{net} Q \rho g}$$

Where P (in W) is the power delivered to the shaft, H_{net}(in m) is net head available at the turbine inlet for power generation. Efficiency of a turbine changes with turbine discharge, net available and the type of the turbine as illustrated in the figure 2.2.

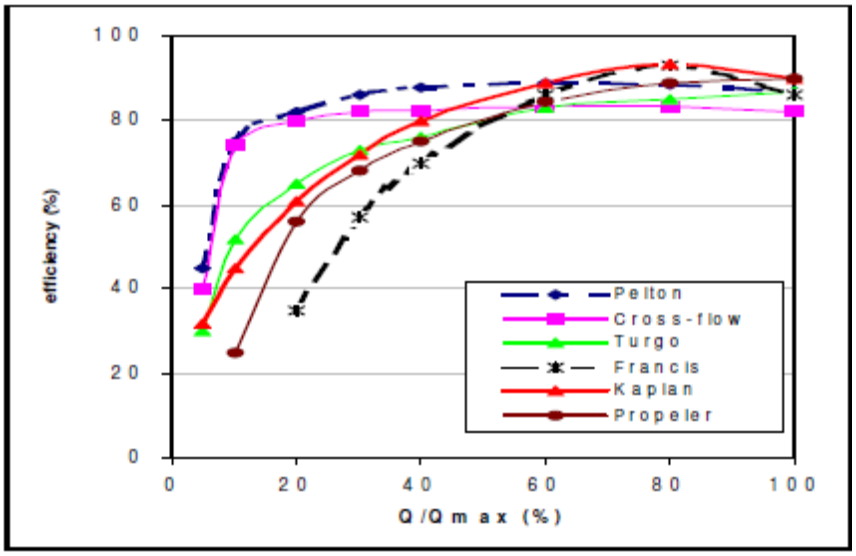

Figure 2.2: Typical efficiency as a function of percentage of the rated discharge for several types of turbines [8]

Also the efficiency of a turbine is highly considered in selecting a turbine for a considered hydro power scheme as to optimize the economic feasibility of the scheme. Figure 2.3 shows chart used for selecting a suitable turbine for a typical mini hydro power scheme.

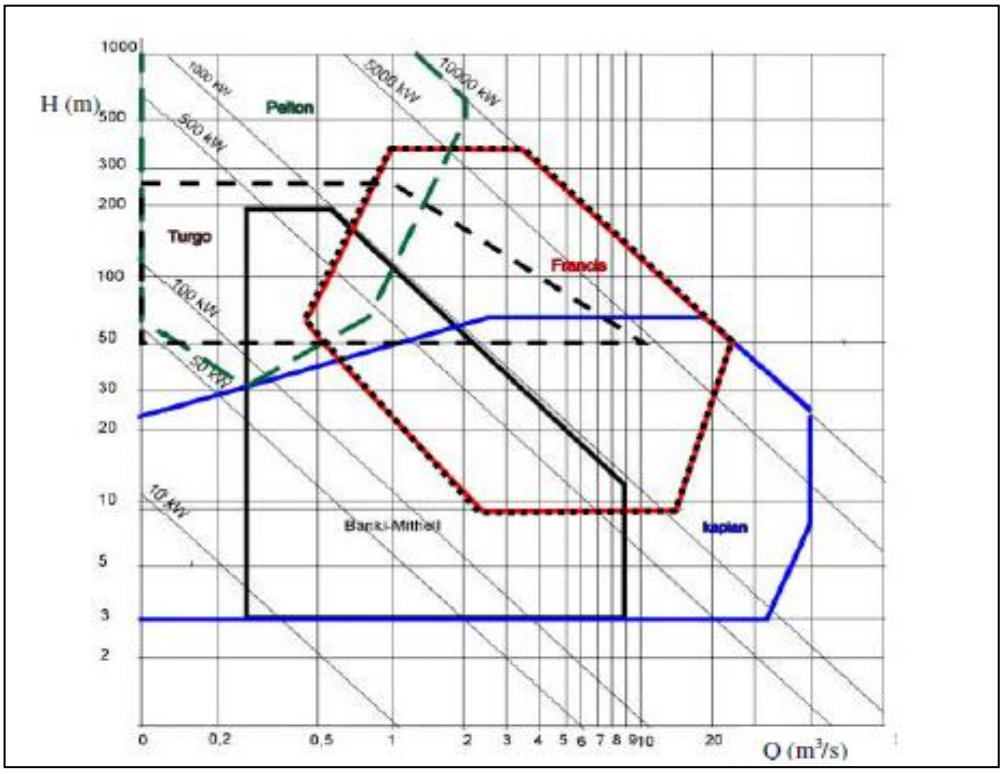

Figure 2.3: Example of hydro turbine range applications [8]

Efficiency of impulse turbines

Impulse turbines are comprised with a runner which injects water to the rotor buckets and one or more nozzles. Hydraulic energy (kinetic energy) associated with the water jet which is injected through the nozzle/s is converted into mechanical energy (kinetic energy) of the rotor blades by hitting the rotor blades. In calculating the efficiency of impulse type turbines power delivered to the shaft can be calculated by dividing active power output by the generator efficiency. Net head available for power generation is calculated by difference of the suction head and the discharge head. As the elevation of both suction and discharge points are same, velocity head of the discharge is negligible and the pressure head at the discharge is zero, net head available for power generation is given by the velocity head at the suction point of the turbine.

Efficiency of reaction turbines

In reaction type turbines both pressure energy and velocity energy of the suction flange are transformed into pressure energy at the discharge flange. Since having a pressurized flow inside the reaction type turbines, pressure heads at the suction and discharge points are different. However the velocity head at the discharge point flange can be negligible. Therefore the net head available for power generation of a reaction type turbine is given by the difference of the sum of pressure head and velocity head at the suction flange and the pressure head at the discharge flange.

Generator efficiency

Through the generator power delivered to the shaft of the turbine is converted into electrical power incurring power losses. Typical energy conversion process of a hydropower scheme is illustrated by Figure 2.4. So the generator efficiency is considered as the ratio of electrical power output to the mechanical power output of the turbine.

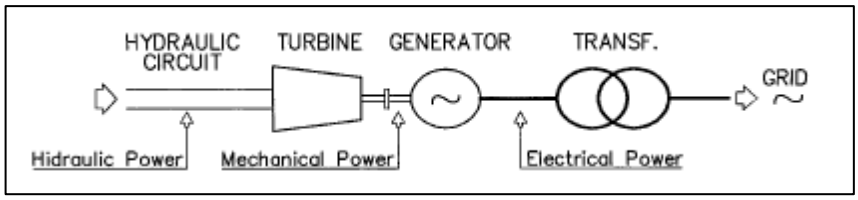

Figure 2.4: Typical power conversion scheme of hydro power plant [8]

Plant overall efficiency

During the hydraulic flow from the diversion point to the output of the generator, energy associated with the hydraulic flow is converted into other types of energies apart from converting to electrical energy. Hence, the overall efficiency of the mini hydro scheme is given by the ratio of power output after the generator to the hydraulic power available at the water intake point of the diversion while hydraulic power available at the diversion point is given by $H_{gross}Q\rho g$ where H_{gross} is determined by the datum head at the diversion point and Q is available stream flow.

2.3. Hydrological assessment of a mini hydro catchment

Hydrological assessment is used to forecast the river flow variations during the operational life of the project. This study basically concerns on the calculation of runoff associated with a particular catchment by estimation of relationships between a particular watershed and rainfall which depend on a variety of factors as mentioned below [9].

- Watershed topography and geology (i.e. bedrock permeability)
- The area of a basin receiving rainfall
- Land use pattern (i.e. agriculture, urban development, forestry operations)
- Drainage density
- Duration of rainfall ,precipitation intensity and type
- Evapo-transpiration rates
- River geometrics
- Climatic season
- Previous weather patterns
- Vegetation type and cover

- River conditions (e.g. dams)
- Initial conditions (e.g. the degree of saturation of the soil and aquifers)
- Soil permeability and thickness

2.3.1. Unit hydro graph method

Dr. U. Rthnayaka of Faculty of Engineering, University of Peradeniya describes unit hydrograph method for estimating hydrological behavior of Bambarabotuwa oya mini hydro power plant in Rathnapura divisional secretariat of Sri Lanka [10]. This hydrological study report covers technical issues and concerns of hydrological aspects of proposed mini hydro plwer plant at Batewela on Bambarabotuwa oya in Rathnapura. Here the origins of the streams and the catchments are located within mountainous catchment in Rathnapura DS division. The stream under consideration, for the proposed development is the Bambarabotuwa oya draining to Kalu Ganga.

Next part of the study is estimating average monthly flows and flow duration curve from rainfall-runoff method. Catchment, draining to weir location is about 7.8 km^2 and it shows a runoff coefficient of 0.82 [10]. This being a small mountainous catchment with rainfall distributed throughout the year and covered with forest & tea, a high amount will flow out of the catchments as calculated under runoff coefficient. Calculated minimum dry weather flow at the weir is about 0.04 m^3/s, while the base flow calculated as the 90 % flow in the stream is 0.14 m^3/s. The driest months, January and February are the periods of very low flows resulting from prolonged dry weather spells.

The catchment area receives high levels of rainfall. The area belongs to the “WM1” Agro Ecological Region in the old scheme and “WM1a” in the new scheme, experiencing rain predominantly during south-west monsoons. The rainfall around the catchment is measured at rain gauging station located in Lellopitiya which is maintained by the estate. The observed daily rainfall for 30 years at this rain gauging station was collected for the analysis. These data of the rain gauging station was collected from department of meteorology, Colombo.

The missing data of the time series are filled using standards methods and the statistical parameters of the rainfall time series is calculated. Summary characteristics of the collected rainfall data shows that the lowest rainfall is expected in the months of January to March. On the other hand April to June and September to November records the highest rainfalls in the year. The annual average of the rainfalls is 3633 mm at Lellopitiya. The number of rainy days in each year based on the observed data of the longest dry period of each year based on the observed data of the considered rain gauging stations are 178 days and 48 days respectively.

Generating discharge data

In the absence of observed runoff data close to the diversion site, daily rainfall data is used to generate the flow discharge at the diversions using synthetic hydrograph to calculate rainfall-runoff relationship. The hydrological model is mainly based on maintaining long term mass balance of rainfall-runoff relationship for both base flows and direct runoff. The evaporation and deep percolation loses of the catchments are considered in the model. However, the deep percolation was not given much importance assuming that in the long run no significant changes occur in the groundwater storage.

The direct runoff of catchment is calculated using the Snyder synthetic unit hydrograph method. The calibration of the models thus considered the observed flow measurements taken during proper inspections. The hydrological model can then be calibrated to get the calculated flows close to the observed flows when the rainfall condition is similar. It should be noted here that the calibration concentrated on fitting the average flows and therefore the extremes may not be very accurate.

As expected from the rainfall, the discharges in the months of January, February and March are the lowest. The catchment shows a runoff coefficient of 0.82. This being a

mountainous catchment with cloud interception and high ground water contribution high amount will flow out of the catchments as calculated under runoff coefficient.

Unit hydrograph derivation

Snyder's synthetic unit hydrograph for the total catchment has parameters as the lengths of the major streams of 5.5 km and the lengths to the centroid as 1.9 km for the diversion location. Accordingly the peak discharge of unit hydrograph is 1.61 m^3/s with a lag time of 8.1 hrs. The base length of the unit hydrograph is 4.0 days. This unit hydrograph is then converted to 24 hr unit hydrograph for rainfall-runoff modeling.

Deriving the time series of discharges

Using the daily rainfall and the unit hydrograph the daily flows were calculated. The flows reached the lowest values in the January-March period. But scattered rainfall in this period has caused intermittent recharge of the groundwater to replenish the base flows time to time. Such rainfall has recovered the base flows except in few occurrences. Calculated minimum dry weather flow at the weir is about 0.04 m^3/s. The base flow calculated as the 90 % flow in the stream is 0.14 m^3/s. The driest months, January and February are the periods of very low flows resulting from prolonged dry weather spells.

2.3.2. HEC-HMS-3.0.1 method

Dr. M.I.M.Mowjood of Department of Agricultural Engineering, University of Peradeniya and Dr.M.M.M.Najim of University of Kelaniya describes HEC-HMS-3.0.1 method for estimating hydrological behavior of Alupola mini hydro power plant in Rathnapura divisional secretariat of Sri Lanka [11]. This hydrological study report was conducted to assess the stream flow at two weir sites of the proposed Alupola mini hydro power project in Alupola oya and Wewelkadura oya in Alupola village in Rathnapura divisional secretariat. Here daily stream flows were computed using HEC-HMS-3.0.1 model developed by US Army Corp of Engineers. Daily

stream flows generated covering 9 year period from 1985 to 1993 at the weir-1 show that mean monthly flows are above or around 1.0 m^3/s in all months except in January and February. Highest flows are expected in May, June, September and October. In case of weir-2, stream flows are more than 1 m3/s in May, June, September, October and November. Dry flows can be expected from January to March. According to the flow duration curve for the total period of the study, 50 % and 75 % probability of daily discharges at weir-1 are 1.2 m^3/s and 0.93 m^3/s, respectively. In weir-2, 50 % and 75 % probability of daily discharges are 0.76 m^3/s and 0.57 m^3/s, respectively. The 100 % probability of minimum daily discharge in weir-1 and weir-2 are 0.19 and 0.12 m^3/s, respectively.

In this consideration, detailed information on stream flow at weir site is cruicial to determine the capacity of the power plant and to ensure its effectiveness. Stream flow consists of surface runoff and base flow. Surface runoff starts during the rain and will last until few hours after the rain ceases. Base flow represents the discharge of aquifer. Base flow increases during the rainy season and continue o contribute to the stream flow for a much longer period even in the dry season. Therefore, the stream flow depends on the rainfall pattern and the retaining characteristics of the catchment.

In this project it is proposed to use water flows from adjacent two streams before both meets to form a single stream. The weir sites are located in Alupola oya and Wewelkadura oya in Alupola village in Rathnapura divisional secretariat. Figure xx shows the catchment boundaries and drainage network of the catchments with respect to the proposed weir sites. Alupola oya originates from Alutwelawisahena mountain at an altitude of 1213 m above msl. The catchment area with espect to the weir sites 1 and two are 3.14 and 2.78 km^2 , respectively. Steep valley slopes with forest are found in both catchments. Combined effects of these features would be rapid runoff response in the catchment. Stream flows in the river would be characterized by large flow volumes during rainy periods immediately followed by moderate flows with based flow contribution after rains ceased.

Rainfall

The catchment comes under low country wet zone (WL1a) receives higher annual rainfall during inter-monsoons and south-west and north-east monsoons. Rinfalls, recorded in Alupola rain gauge station can be used for the hydrological analysis. Average annual rainfall is 421 mm based on 9 years data from 1985 to 1993.

Distribution of monthly rainfall

The distribution of mean monthly rainfall for Alupola for 9 years from 1985 to 1993 shows the catchment receives higher rainfall in May, June, September, October and November. Highest rainfall was observed in the months of May and October. Most dry months are January and February.

Daily rainfalls for the preparation of daily stream flows

Analysis of daily rainfall data shows that on an average number of rainy days per year is 191. Number of rainy days has varied between 171 and 218 during the period studied. The number of rainy days is higher compared to high rainfall regions of the central highlands which receive rainfall as many as 210 of the year.

Considering the probability of daily rainfall nearly 34 % of the time basin receives rainfall between 2-20 mm. This will help to retain the soil moisture in upper zones and the higher rainfalls followed by will result in faster runoff response. About 8 % of the occurrences are above 40 mm.

Heavy rainfall depths usually produce flood discharges and resulting flows would be difficult to capture. On the other hand, a considerable share of lower range will be lost due to interception and evaporation. Due to this fact, nearly 82 % of the time river flow will be dominated by the base flow component. On the other hand nearly 8 % of the time there will be considerably heavy flows.

2.4. Energy potential of mini hydro power scheme

Annual energy potential of a selected mini hydro scheme basically depends on the flow variation associated with its' catchment and the elevation difference between weir and the power house which is also considered as the differential gross head, which represents total hydraulic energy associated with a unit flow of the run off river scheme. Conversion of the hydraulic potential energy of a flow in to electrical energy is the basic concept of hydro power generation in a mini hydro scheme.

Gross head

According to the principle of energy balance, energy associated with the river flow at the point of intake is subjected to various losses between the intake point and the tailrace. Gross head of the mini hydro scheme is considered as the "Head" at the intake point as mentioned by equation 2.1.

Net head

The net head of a mini hydro power scheme is considered as the head available for power generation at the turbine inlet. If the head available at the turbine inlet is H_A and the head available at turbine outlet is H_B, Head available for power generation, i.e. Net Head, H_{AB} is given by;

$H_{AB} = H_A - H_B$

$$= Z_A + \frac{P_A}{\rho g} + \frac{{V_A}^2}{2g} - \left[Z_B + \frac{P_B}{\rho g} + \frac{{V_B}^2}{2g}\right]$$

As $Z_A = Z_B$;

$$\boldsymbol{H_{AB} = \frac{P_A - P_B}{\rho g} + \frac{{V_A}^2 - {V_B}^2}{2g}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{2}.1)$$

Methods of calculation of net head associated with impulsive type and reaction type turbines are varied as for impulsive turbines, the downstream pressure is considered as atmospheric pressure and velocity of downstream is negligible, while for reaction

turbines, downstream pressure is considered as the static pressure of draft tube outlet and velocity of that is considered as negligible.

Canal loss

The gross energy of a mini hydro power scheme is lost when flowing from intake point to forebay tank. This energy loss is referred to canal loss of the scheme. Energy is lost in the canal basically due to the friction of canal walls and bed materials. Canal loss can be calculated by the head difference between the intake point and forebay tank reservoir level.

Penstock loss

During the water is flown trough the penstock, energy associated with the flow from forebay tank is subjected to frictional losses by the roughness of the penstock material and velocity head losses at entry, bends, joints, reducers, expansions and exit which are governed by following equations.

Head loss occurred inside the pipes is governed by Darcy - Weisbach formula [12] as given in equation 2.2.

$$\Delta h_{f1} = f\frac{LV^2}{2Dg} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{2}.2)$$

Where: Δh_f is the head loss occurred inside the pipe length,

f is Moody friction factor governed by the Moody diagram with corresponding to Reynolds number and relative roughness of the pipe,

L is pipe length considered,

V is average velocity of the water flow,

D is hydraulic diameter of the pipe cross section and

g is acceleration due to gravity.

Likewise the head loss occurred at entry, bends, joints, reducers, expansions and exit is given by the common formula given in equation 2.3

$$\Delta h_{f2} = K\frac{V^2}{2g} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{2}.3)$$

Where: Δh_f is the head loss occurred at the considered,

K is head loss coefficient at considered irregularity,

V is average velocity of the water flow at the irregularity,

g is acceleration due to gravity.

So the total penstock loss is given by the sum of equations 2.2 and 2.3 as mentioned in equation 2.4 below.

$$\Delta \boldsymbol{h_f} = \boldsymbol{f}\frac{\boldsymbol{LV^2}}{\boldsymbol{2Dg}} + \frac{\boldsymbol{KV^2}}{\boldsymbol{2g}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\boldsymbol{2}.4)$$

3. METHODOLOGY

3.1. Introduction

Four operational mini hydropower plants (MHP) situated consecutively in a raw in Bambarabotuwa Oya of upper Kalu Ganga catchment are selected for the study. Figure 3.1 shows the relative positions of selected mini hydropower schemes illustrated in an enlarged section of the 1: 50,000 topographic map of Balangoda. Performance data were collected from Bambarabotuwa Oya-III MHP (MH1), Bambarabotuwa Oya-II MHP (MH2), Bambarabotuwa Oya-I MHP (MH3) and Denawaka Ganga MHP (MH4) in Ratnapura as shown in Figure 3.1 below and project parameters of above schemes are illustrated in Appendix-1. For the analysis, energy generation data and plant breakdown records of consecutive power plants were obtained.

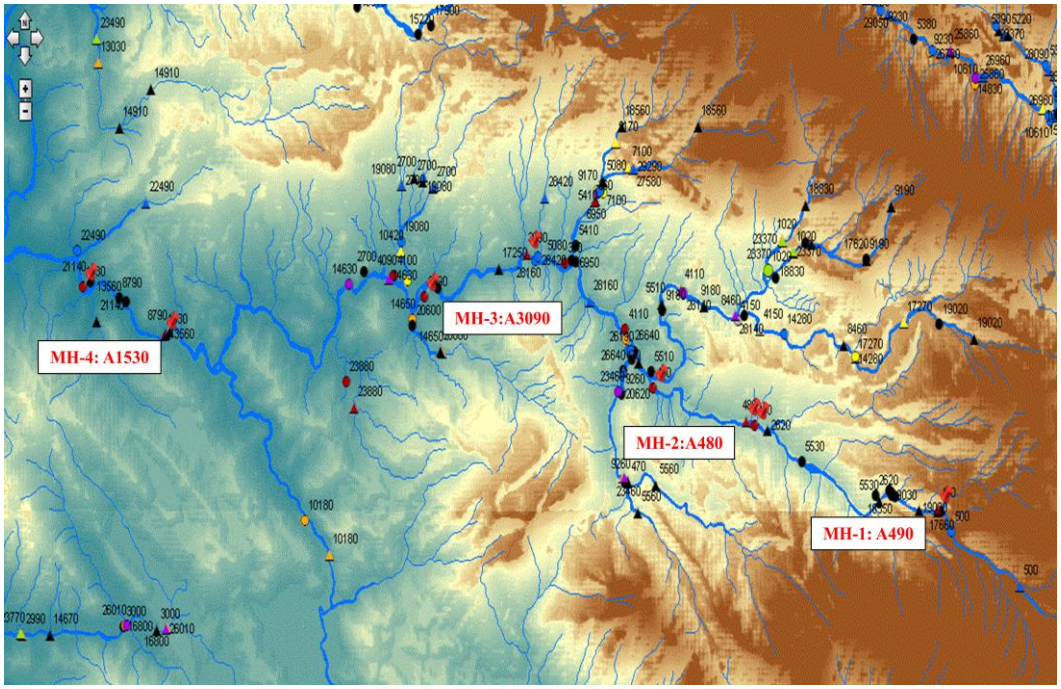

Figure 3.1: Selected mini hydro power plants [13]

The main objective of this study is to construct a relationship between energy supplied from a selected mini hydro power plant with the same of the adjacent mini hydro plant and operational characteristics of two schemes.

3.2. Procedure for data analysis

Basically the annual average monthly energy generations are considered as the major performance indicator of the considered mini hydro scheme. As this performance indicator depends on the flow variation associated with the catchment of the scheme and elevation difference of the weir and power house, the analysis is mainly focused on the behavior of the catchment characteristics and the topography of the scheme where catchment characteristics of the selected mini hydro schemes are considered same. Following two approaches are considered in the data analysis.

- Forecasting annual energy generation of a scheme using performance data of upstream operational mini hydro schemes
- Forecasting annual energy generation of a scheme using performance data of downstream operational mini hydro schemes

4. ANALYSIS

4.1. Introduction

In the analysis, performance data of four operational mini hydro power plants situated in a row off the upper catchment of Kalu Ganga basin. The project characteristics of those plants are shown in Table 4.1. First the annual energy generation of MH2 is forecasted using the actual energy generation of MH1 which is situated upstream to the MH2. As it is vital to get normalized energy generation of MH-1 which provides unit energy generation of the plant per unit catchment area and a unit differential gross head is considered. Subsequently, energy generation of MH3 and MH4 power plants situated downstream to MH1 are estimated following the same procedure. Likewise, Energy generation of MH4, MH3 from that of MH2, Energy generation of MH4 from that of MH3, Energy generation of MH1, MH2, MH3 from that of MH4, Energy generation of MH1,MH2 from that of MH3, Energy generation of MH1 from that of MH2 are forecasted.

Table 4.1: Project characteristics

Project Parameter	MH1	MH2	MH3	MH4
Gross Head (m)	320	63	65	29
Design Flow (m^3/s)	1.25	2.50	4.1	20.00
Canal Length (m)	1000	1000	2500	1600
Canal Cross Section Area (m^2)	0.5	1.0	2.0	8.00
Penstock Length (m)	1000	500	800	125
Penstock diameter (mm)	800	1000	1200	1500
Penstock Cross Section Area (m^2)	0.55	0.79	1.20	5.30
Turbine Type	Pelton	Francis	Francis	Francis
Design Capacity (kW)	4000	3000	3200	7200

The design capacities obtaining using first principals and the sensitivity analysis are illustrated in appendix C.

4.2. Forecasting energy generation of downstream scheme by performance data of upstream schemes

Monthly actual energy generation of MH1, MH2, MH3 and MH4 which is situated upper most catchment of Bambarabotuwa Oya flown through upper Kalu Ganga catchment and energy generation estimated by using current model used in SEA are shown in figures 4.1 thru 4.4.

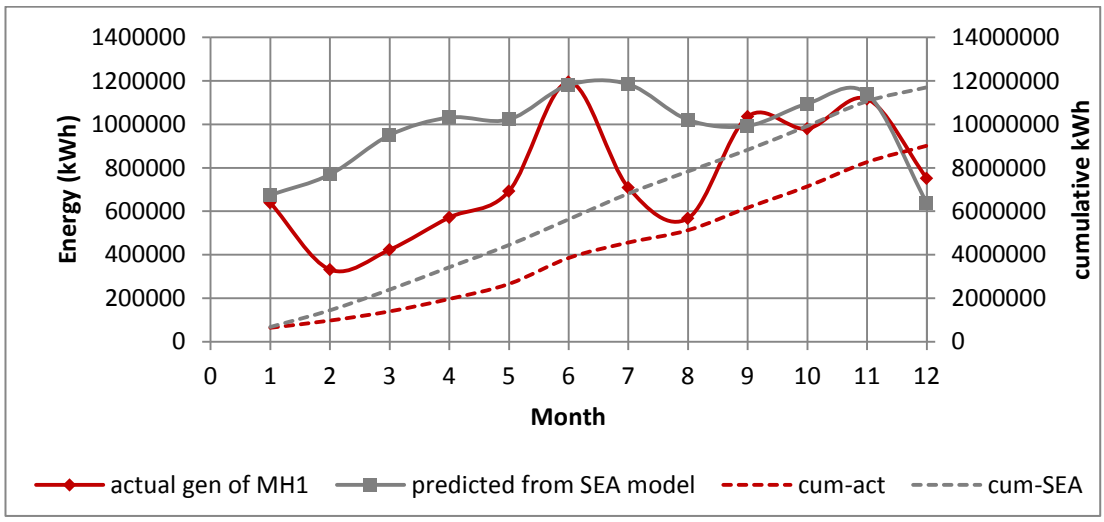

Figure 4.1: Actual energy generation and predicted energy generation by current model for MH1

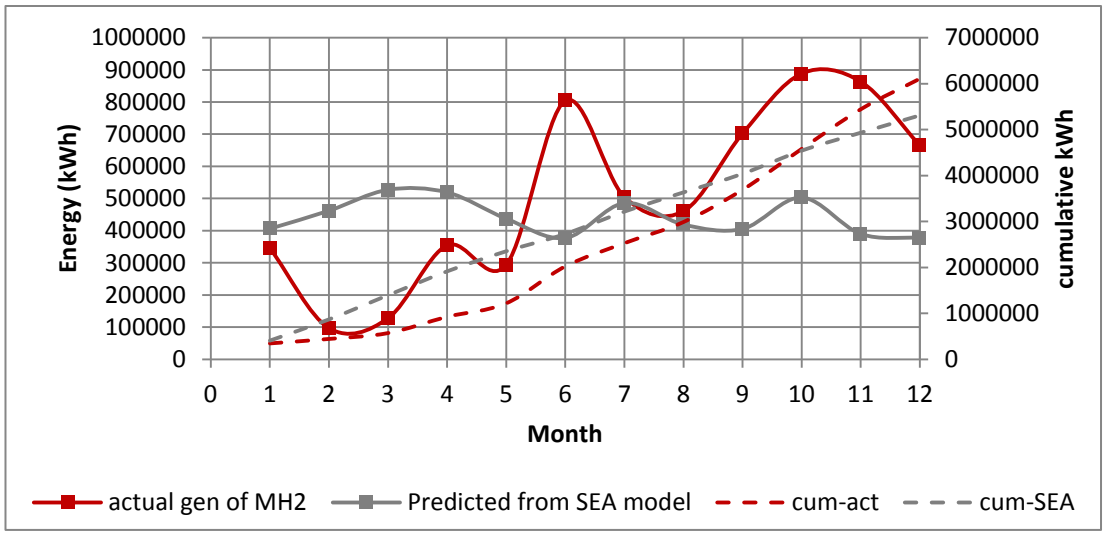

Figure 4.2: Actual energy generation and predicted energy generation by current model for MH2

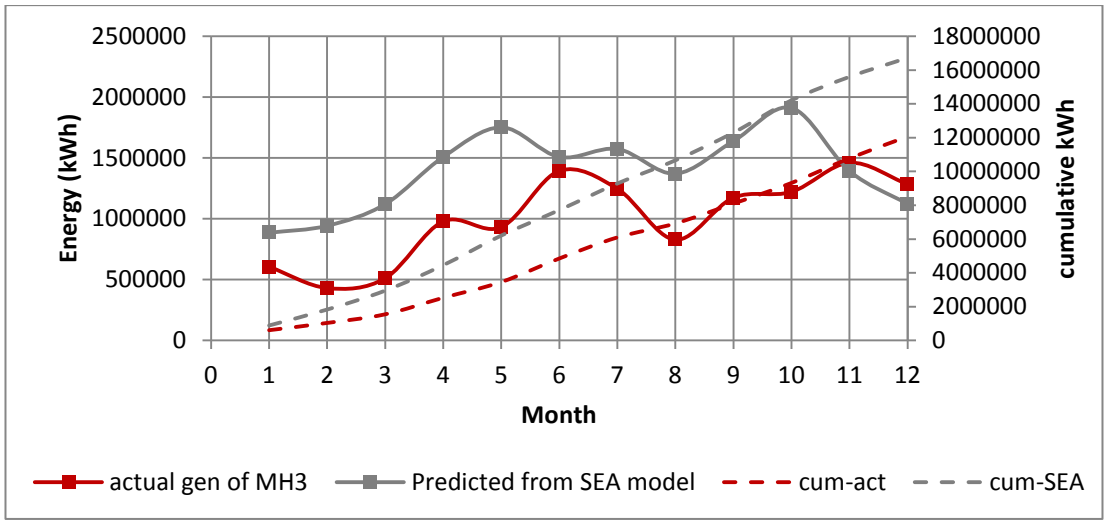

Figure 4.3: Actual energy generation and predicted energy generation by current model for MH3

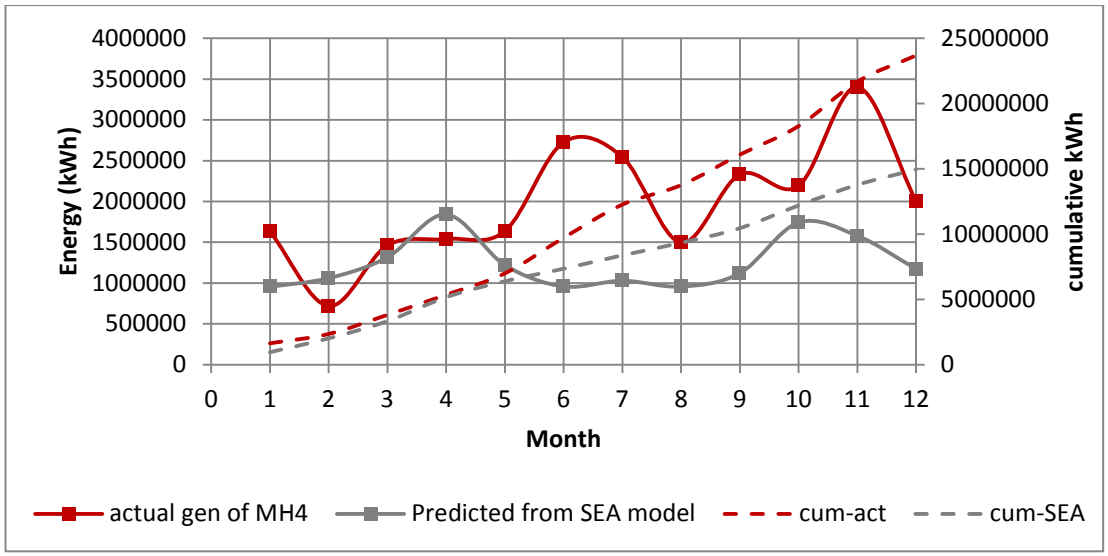

Figure 4.4: Actual energy generation and predicted energy generation by current model for MH4

Forecasting energy generation of MH2

In this study energy generation of MH2 is predicted by associating energy generation data of MH1 which is situated upstream to MH1. Energy generation associated with unit catchment area and a unit differential gross head of the upstream catchment is considered as same for the downstream catchment where MH2 is nurtured. Figure 4.5 and 4.6 show the variations of monthly energy generations predicted from current

model and new model. In addition, the energy generation associated with the river flow derived from recent rainfall data which corresponds to the operational period of MH2 is also plotted in above figures 4.5 and 4.6.

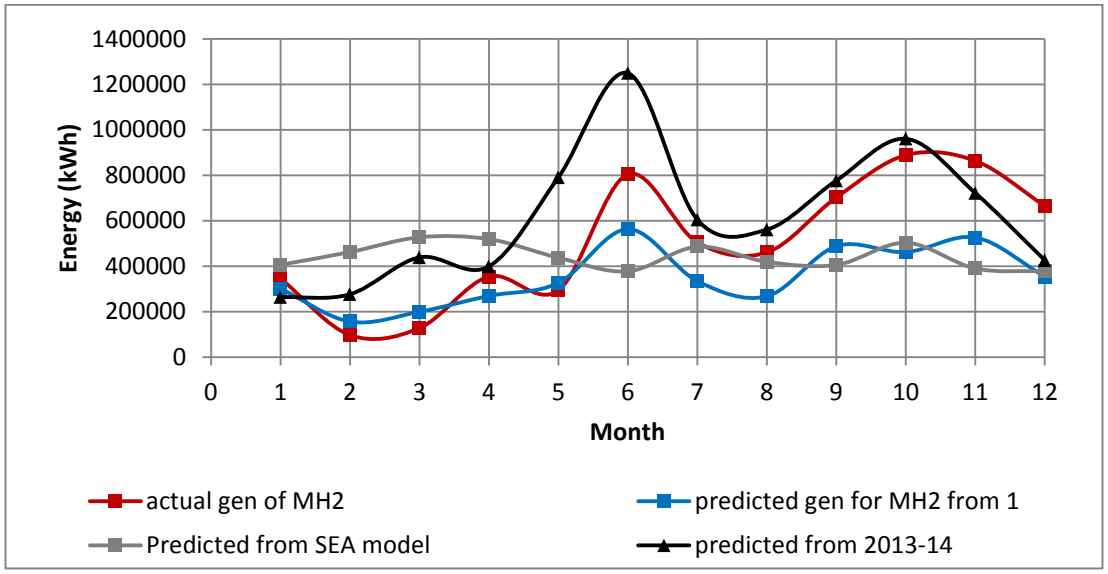

Figure 4.5: predicted energy generation for MH2

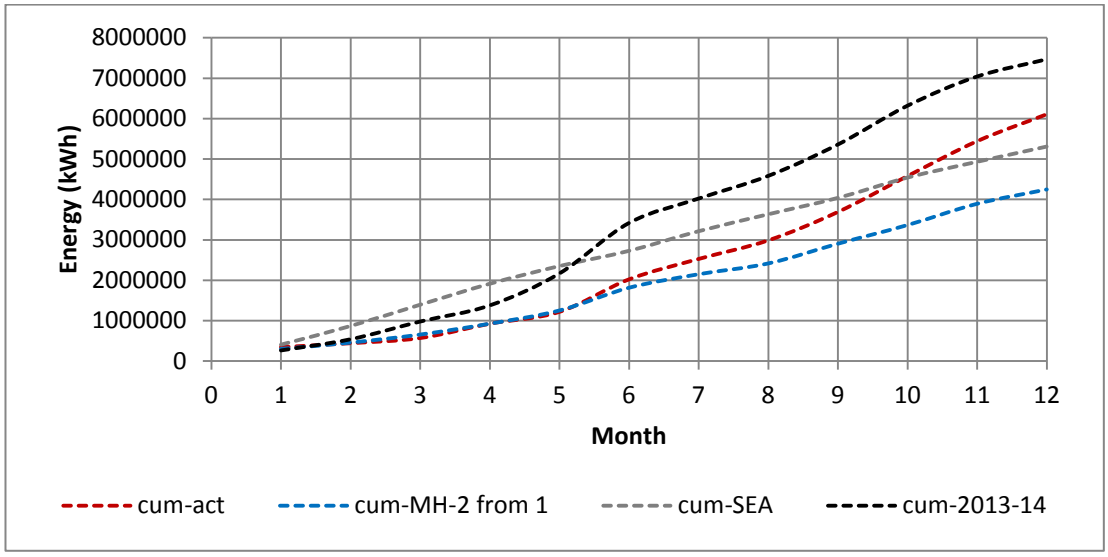

Figure 4.6: cumulative energy generation for MH2

Forecasting energy generation of MH3

Further, predicted energy generation of MH3 can be plotted using performance data of MH2 and MH1 which are situated upstream to MH3 according to the same

procedure discussed above. Figures 4.7 and 4.8 illustrate the energy comparison for MH3.

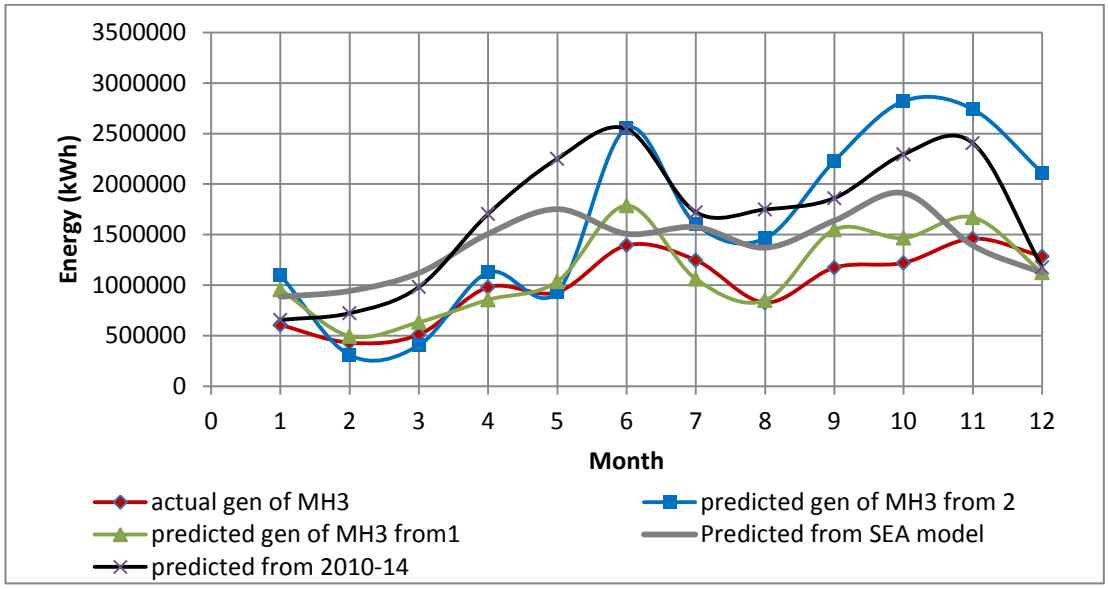

Figure 4.7: predicted energy generation for MH3

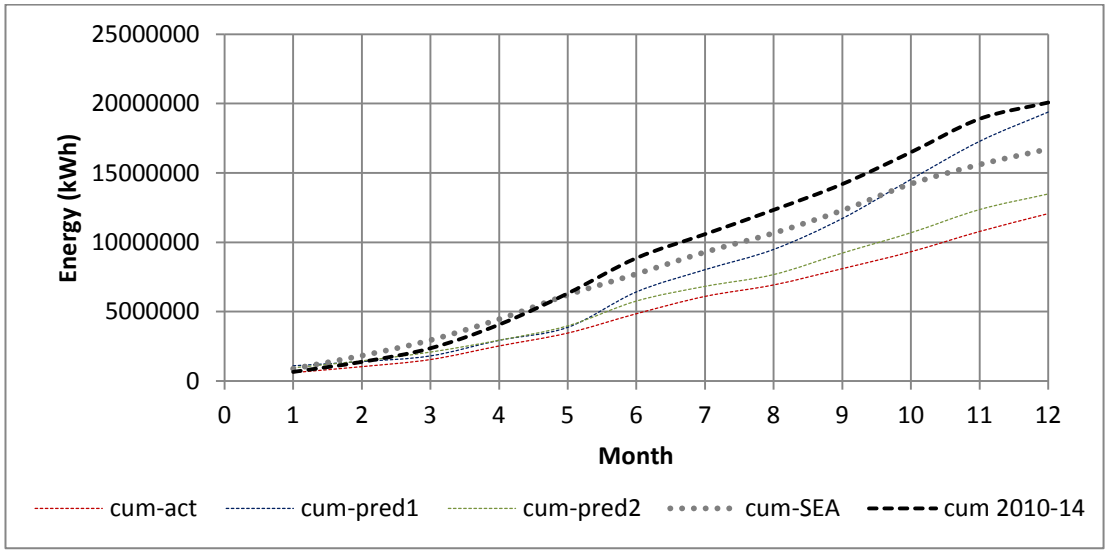

Figure 4.8: cumulative energy generation of MH3

Forecasting energy generation of MH4

Since there are 3 mini hydro schemes are situated upstream to MH4, energy generation of MH4 can be plotted using performance data of MH3, MH2 and MH1

which are situated upstream to MH4 according to the same procedure discussed above. Figures 4.9 and 4.10 illustrate the energy comparison for MH4.

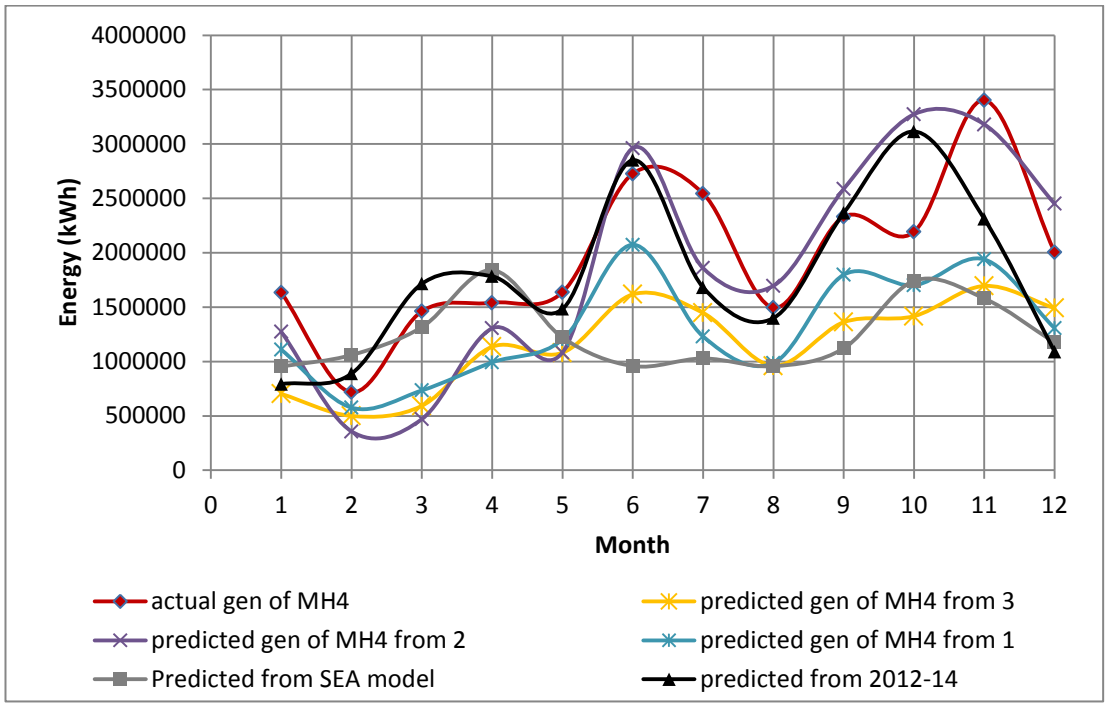

Figure 4.9: predicted energy generation for MH4

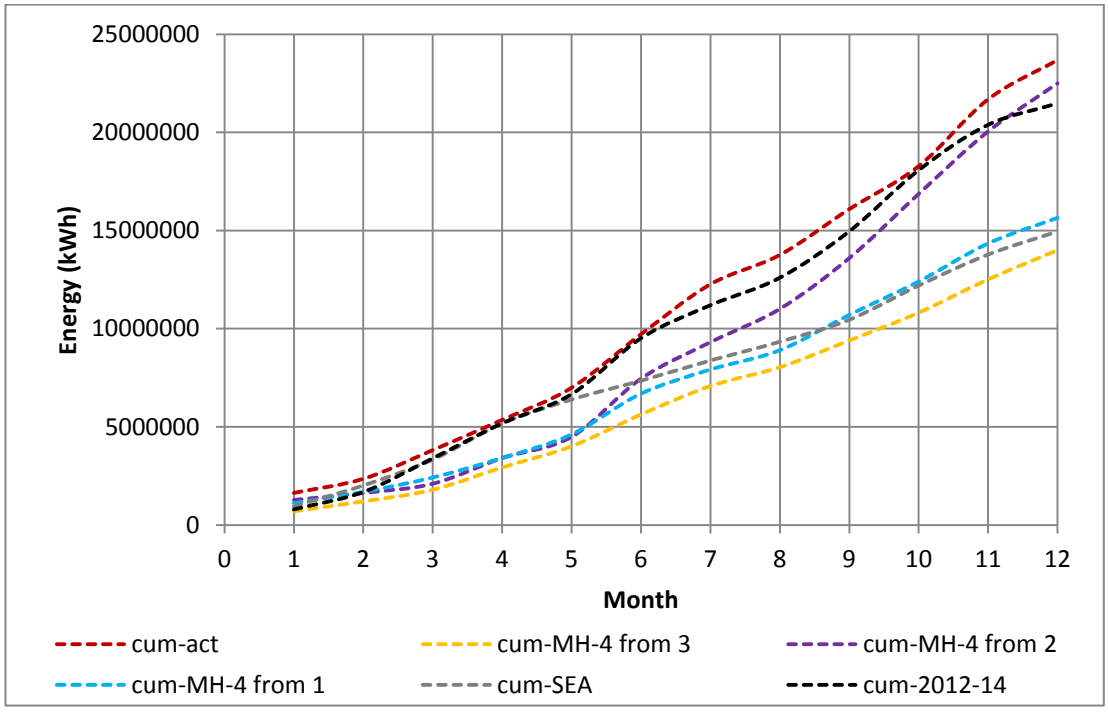

Figure 4.10: cumulative energy generation of MH4

4.3. Forecasting energy generation of upstream scheme by performance data of downstream scheme

It is also possible to estimate energy generation of upstream mini hydro schemes using performance data of downstream mini hydro schemes if there exist operational schemes downstream to the selected site.

Forecasting energy generation of MH3

Here the energy generation of MH3 is predicted by associating energy generation data of MH4 which is situated downstream to MH3. Energy generation associated with unit catchment area and a unit differential gross head of the upstream catchment is considered according to the same procedure mentioned above. Figures 4.11 and 4.12 show the variations of monthly energy generations predicted from current model and the new model and energy generation associated with the river flow derived from recent rainfall data which corresponds to the operational period of MH3 is also plotted in the same figures.

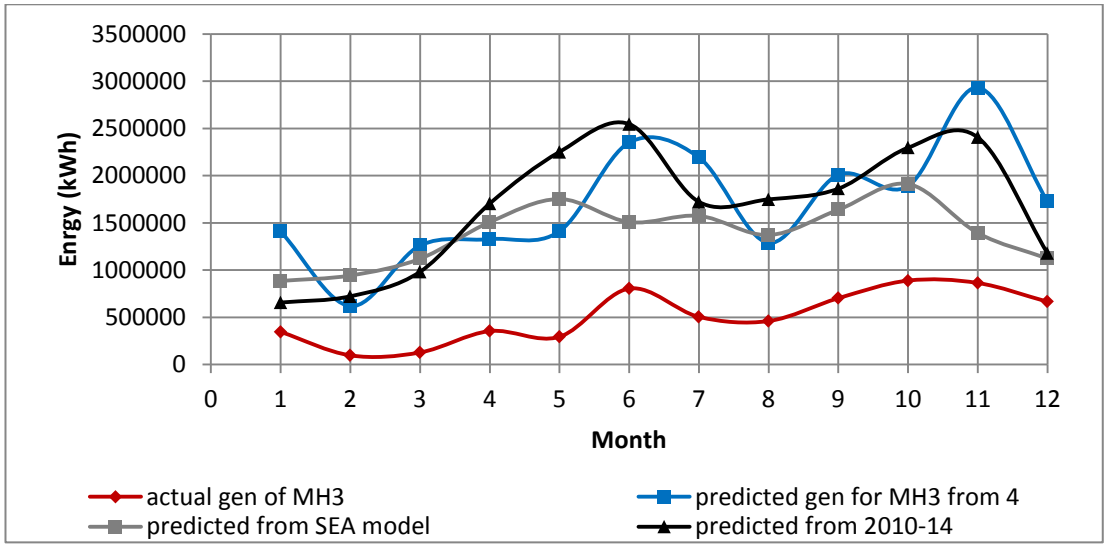

Figure 4.11: predicted energy generation for MH3

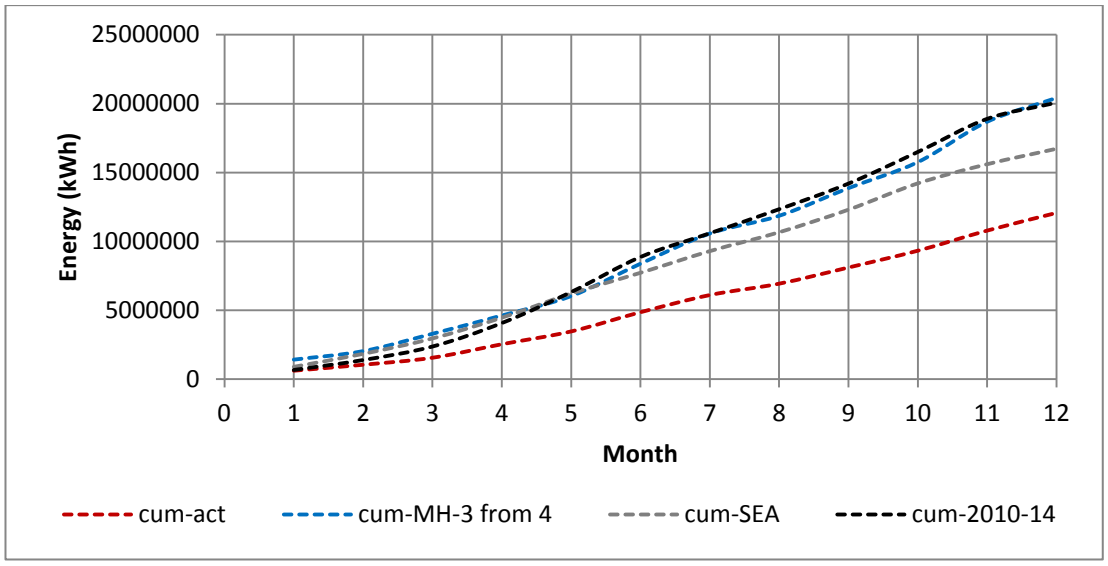

Figure 4.12: cumulative energy generation for MH3

Forecasting energy generation of MH2

Further, predicted energy generation of MH2 can be plotted using performance data of MH3 and MH4 which are situated downstream to MH2 according to the same procedure discussed above. Figures 4.13 and 4.14 illustrate the energy comparison for MH2.

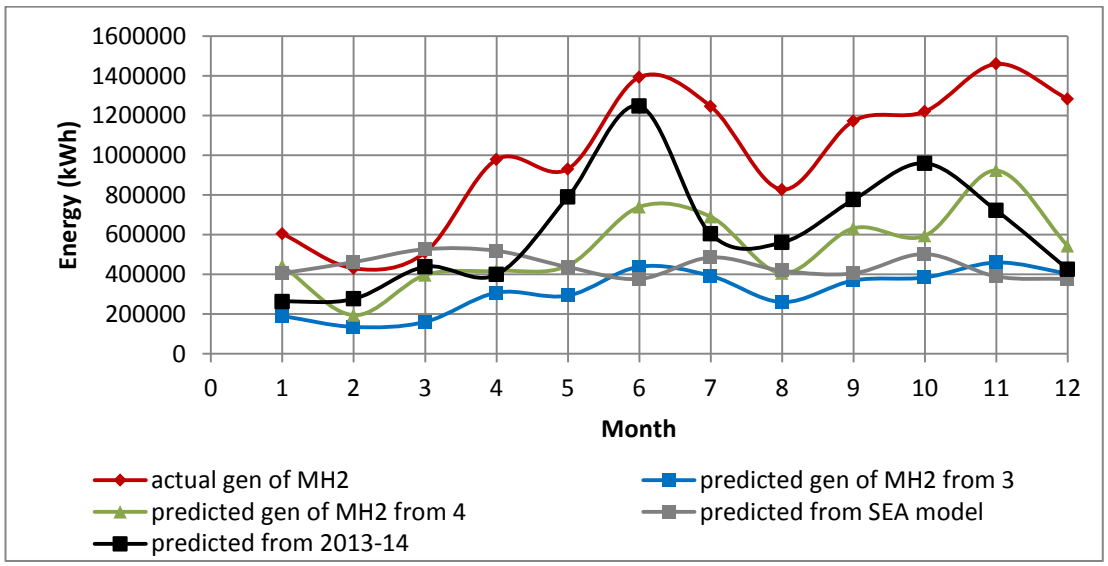

Figure 4.13: predicted energy generation for MH2

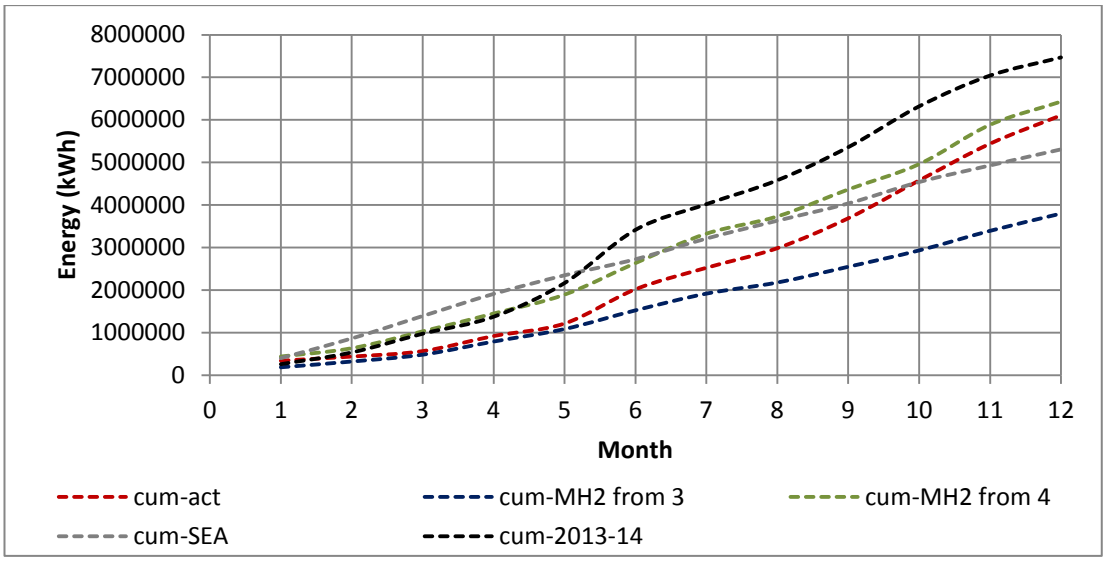

Figure 4.14: Cumulative energy generation of MH2

Forecasting energy generation of MH1

Energy generation of MH1 can be plotted using performance data of MH3, MH2 and MH1 which are situated downstream to MH1 according to the same procedure discussed above. Figures 4.15 and 4.16 illustrate the energy comparison for MH1.

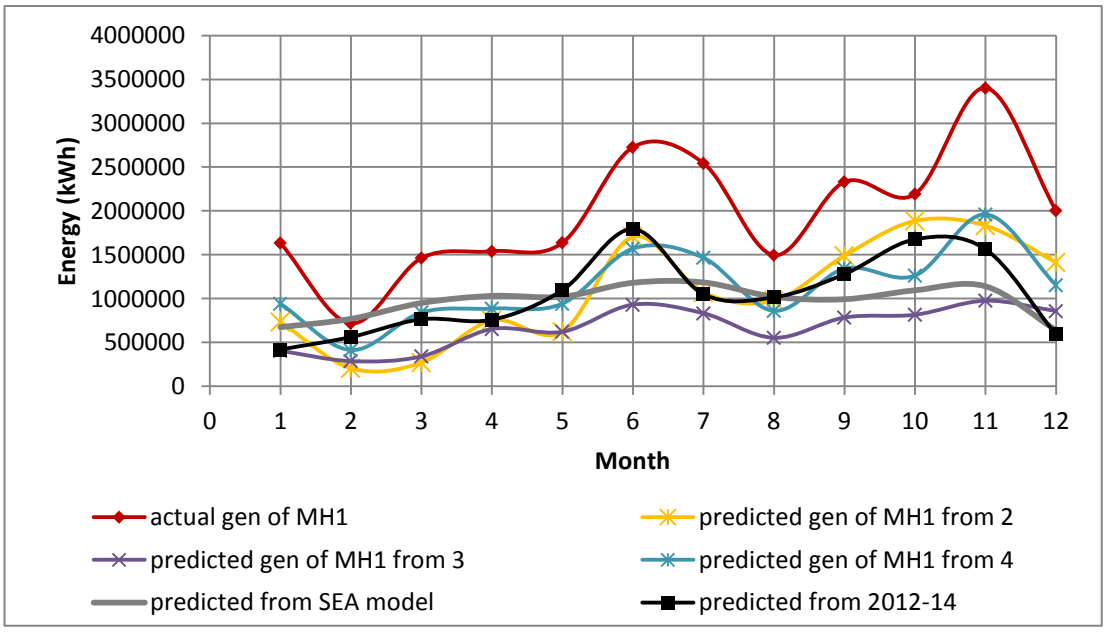

Figure 4.15: Predicted energy generation for MH1

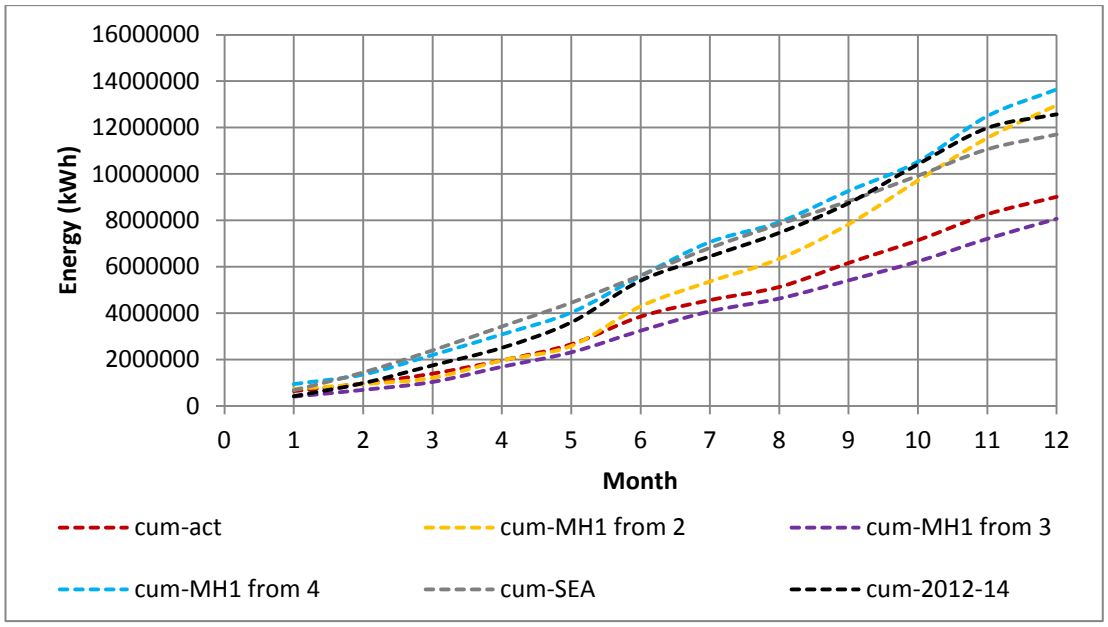

Figure 4.16: Cumulative energy generation of MH1

4.4. Head flow product of the scheme

For all flow mini hydro power schemes it is derived a term for the product of head and average river flow which has the dimensions of hydraulic duty of fluid flow systems. Since product of stream flow and gross head of the scheme is represented by energy generation figure, relative factor is deviated only by a scalar factor which is identical to the site and also governed by the hydrology of the scheme only.

Figure 4.17 shows the relative results obtained for head flow product of four schemes where any significant relationship is hard to be obtained.

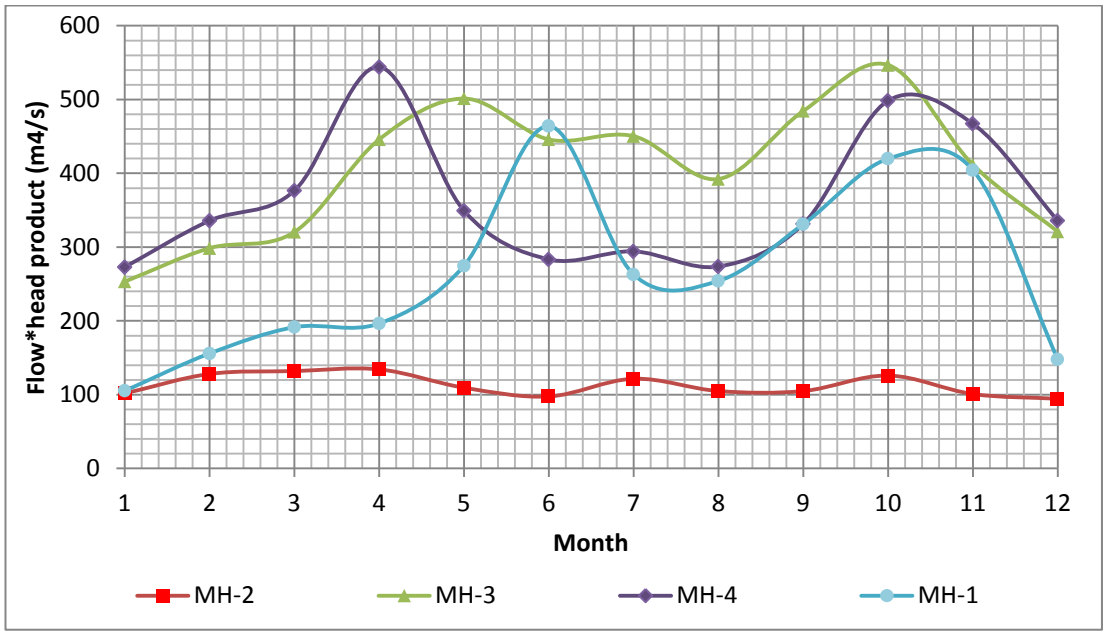

Figure 4.17: Head flow product of the schemes

5. RESULTS AND DISCUSSION

5.1. Present energy estimation criteria

Through the analysis it is explored the relationships among energy generation of a selected mini hydro scheme with the other mini hydro schemes situated upstream and downstream to the project. It is proposed a new model for forecasting annual energy generation of a potential mini hydro development site. Currently Sri Lanka Sustainable Energy Authority uses a model based on Geographical Information System (GIS) along with average annual rainfall data to estimate energy potential of the site.

In this model, installed capacity is calculated using equation 5.1.

$$\boldsymbol{P = \eta Q H \rho g / 1000} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.1)$$

where, $\boldsymbol{P}$ is installed power in kW, $\boldsymbol{Q}$ is design flow in m^3/s, $\boldsymbol{H}$ is design differential gross head in m, $\boldsymbol{\rho}$ is density of water in kg/m^3 and $\boldsymbol{g}$ is gravitational acceleration in ms^{-2}. The overall efficiency of the mini hydro scheme, $\boldsymbol{\eta}$ is considered in this model is 55% which compensates 10% energy loss in head race canal, 20% loss in penstocks, 20% loss in turbine and 5% loss in generator.

Then the modeled energy generation is compared with actual energy generation which is corrected by subtraction of planned and unplanned outages corresponding to considered scheme.

5.2. Forecasted river flows

Monthly average river flow at the weir of MH1 is estimated by the area-rainfall method with the aid of GIS database of SEA. River flow is estimated by multiplying the catchment area and rain fall on the catchment as governed by the Thieson's polygons method of hydrological river flow model widely used by hydrologists. Here the catchment area is subdivided in to polygons where equal rainfall is received equally through the area. Equation 5.2 illustrates the way of estimating river flow.

$$Q = C \times \sum catchment\ area\ included\ in\ the\ polygon \times Rainfall\ recived\ to\ the\ polygon \quad \ldots\ldots\ldots\ldots\ldots\ldots (5.2)$$

where C is flow constant which is considered as 0.70 in the current hydrological model. Flow duration curve for the river flow at the weir of MH1 is plotted in figure 5.1. Design powers corresponding to each plant factor is also plotted in figure 5.1.

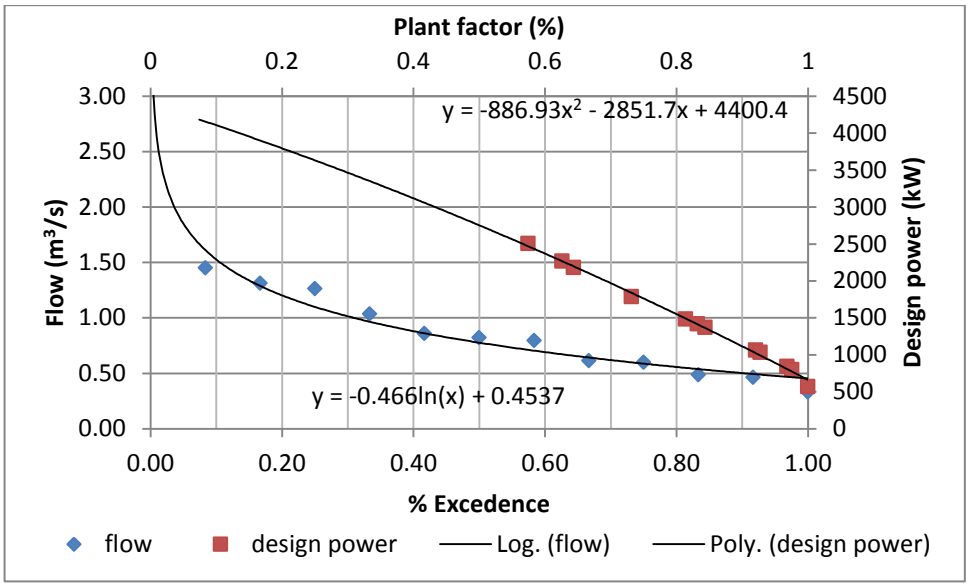

Figure 5.1: Flow duration curve and design power curves of MH1 catchment

Design power of the power plant is determined in a way which enables the power plant to operate in 40% plant factor as recommended by the power sector regulating agencies. According to the equation 5.3, the design power of MH1 should be 3117 kW and the design flow would be 1.87 m^3/s according to the figure 5.2 which shows the variation of design flow verses design power.

$$y = -886x^2 - 2851.7x + 4400.4 \quad \ldots\ldots\ldots\ldots\ldots\ldots (5.3)$$

where, y is design power and x is plant factor.

Accordingly flow duration curves and design power curves and design flow vs design power curves corresponding to MH2, MH3 and MH4 are shown in figures 5.3 thru 5.8.

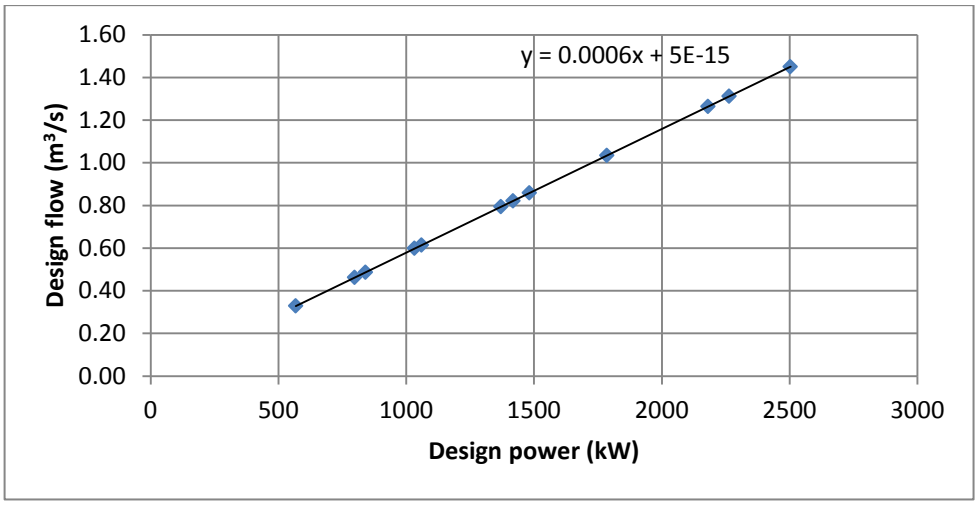

Figure 5.2: Design flow vs design power of MH1

According to figure 5.3 and 5.4 the design power of MH2 should be 1980kW and the design flow would be 5.74 m3/s.

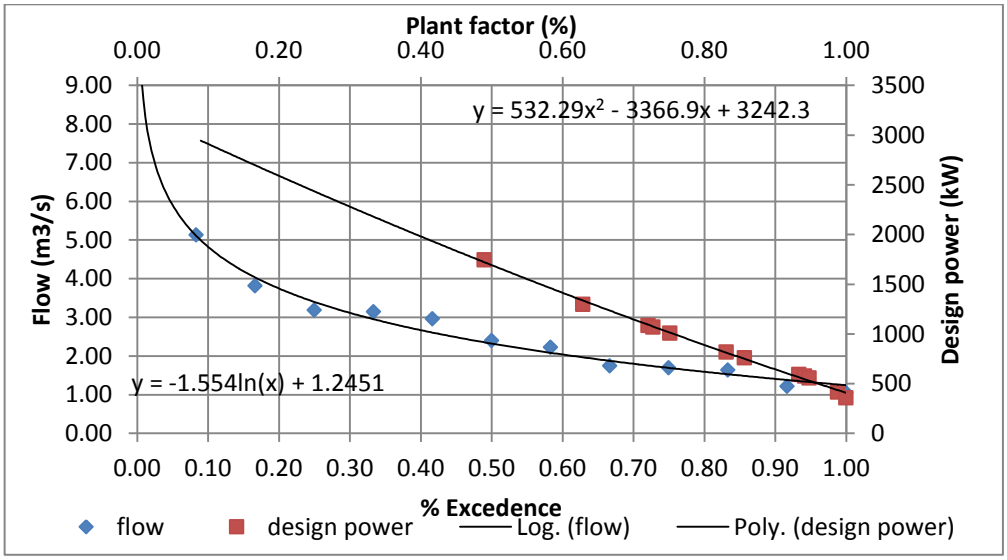

Figure 5.3: Flow duration curve and design power curves of MH2 catchment

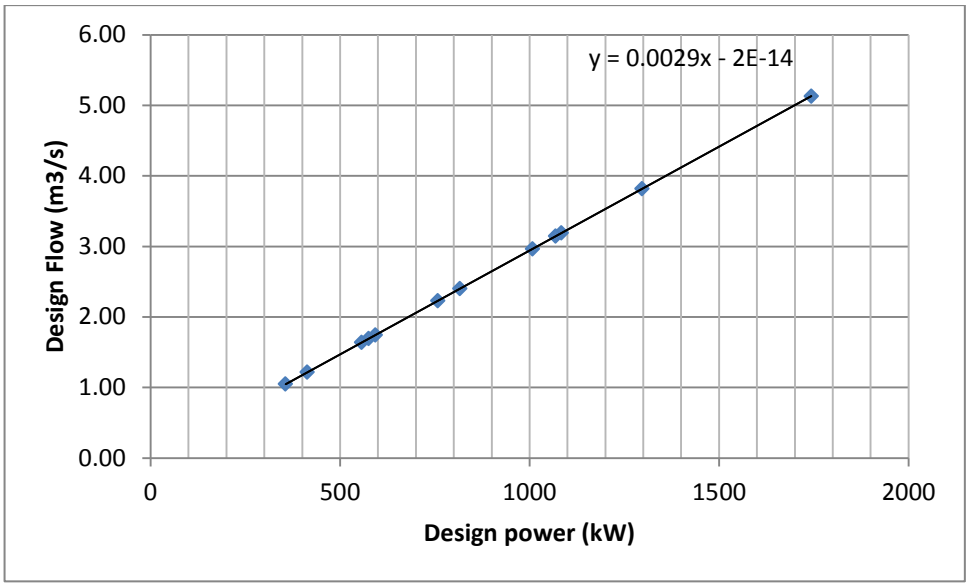

Figure 5.4: Design flow vs design power of MH2

According to figure 5.5 and 5.6 the design power of MH3 should be 4278kW and the design flow would be 12.40 m3/s.

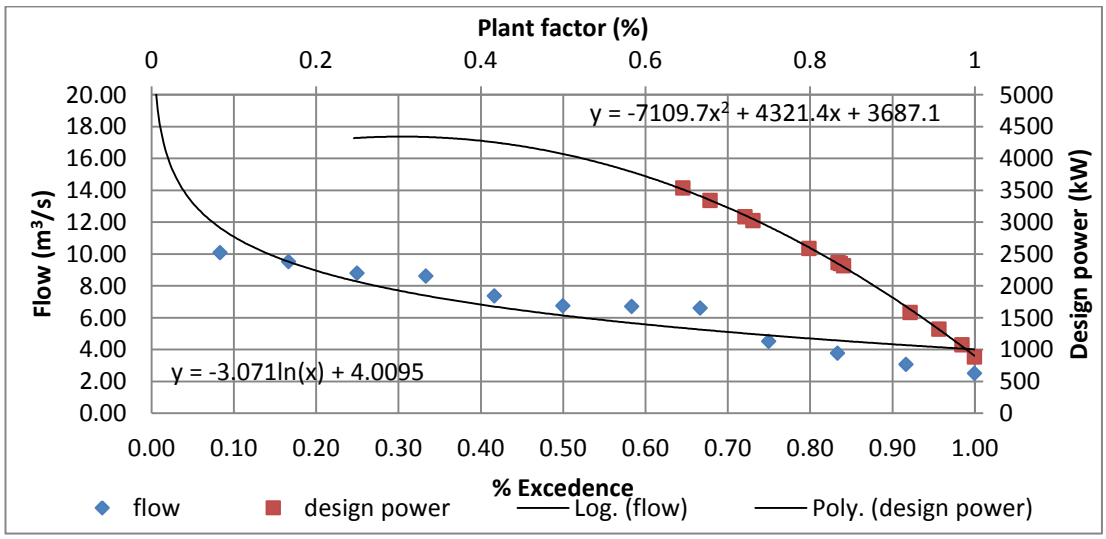

Figure 5.5: Flow duration curve and design power curves of MH3 catchment

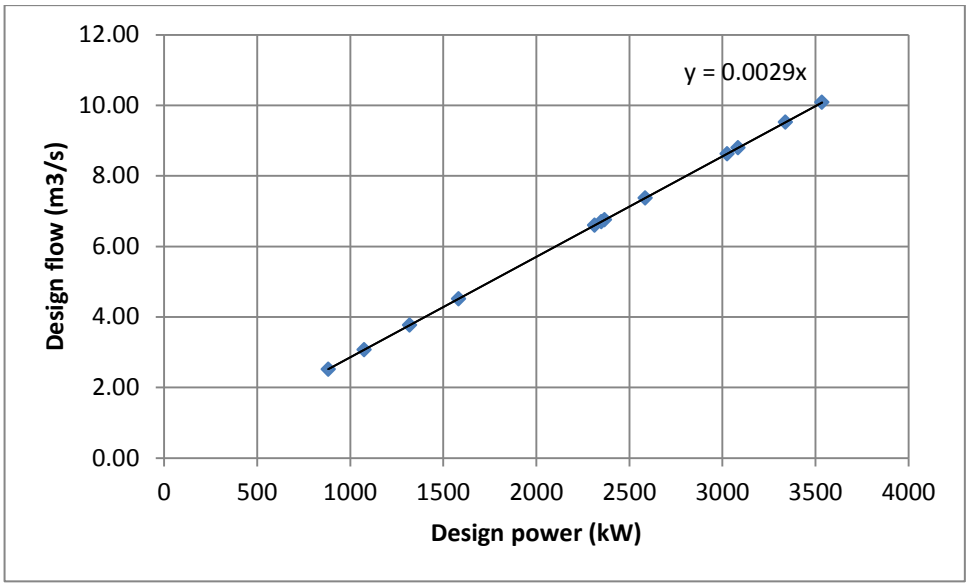

Figure 5.6: Design flow vs design power of MH3

According to figure 5.7 and 5.8 the design power of MH4 should be 5129kW and the design flow would be 32.83 m3/s.

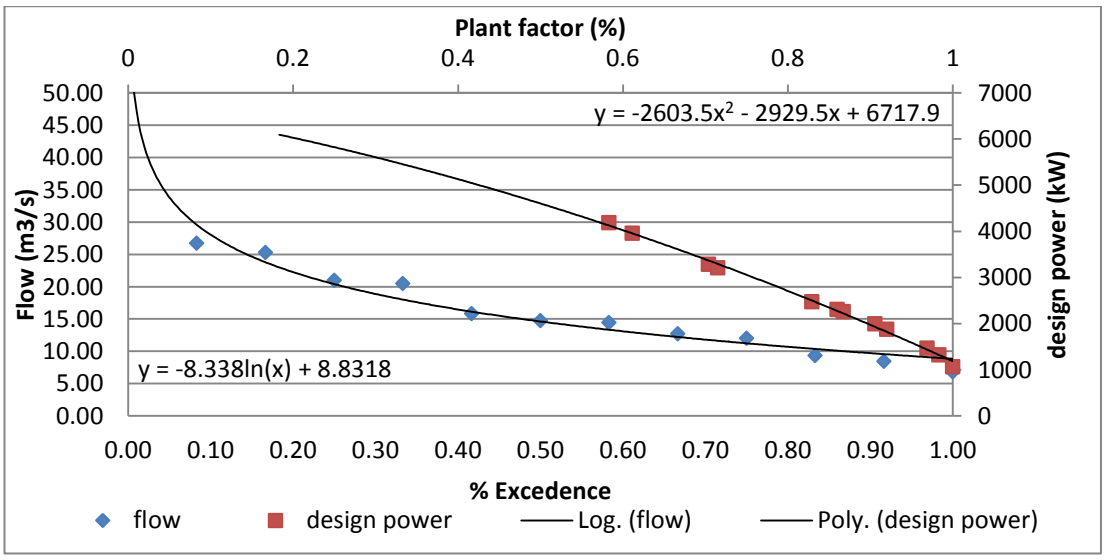

Figure 5.7: Flow duration curve and design power curves of MH4 catchment

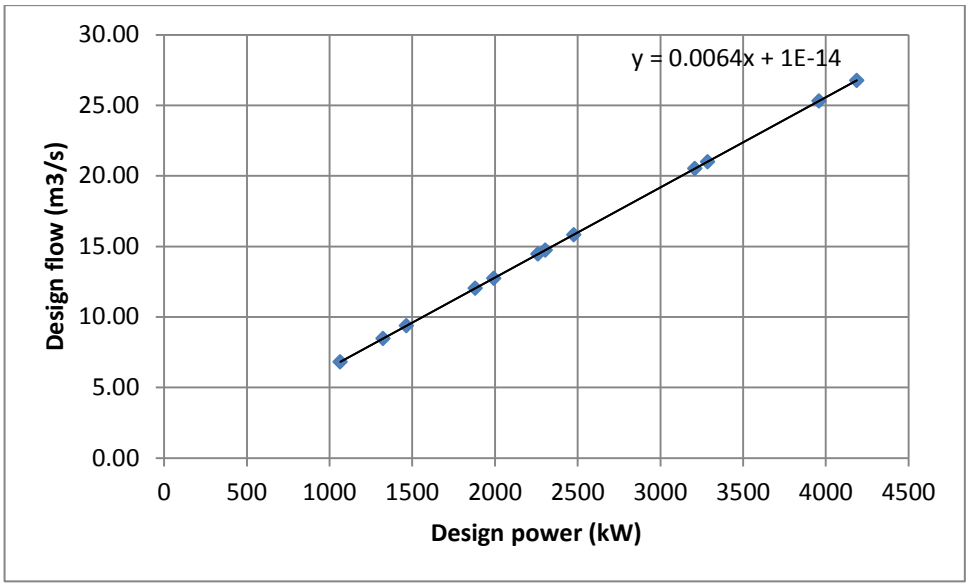

Figure 5.8: Design flow vs design power of MH4

5.3. Actual vs forecasted energy

Tables 5.1 thru 5.4 illustrates the comparison of actual energy generation data of MH1 with different criteria of forecasting.

Table 5.1: Energy comparison of MH1 with criteria-1

Month	Actual generation (GWh)	Predicted generation by SEA model (GWh)	% Difference
Jan	0.64	0.67	5.6%
Feb	0.97	1.44	48.7%
Mar	1.39	2.39	71.8%
Apr	1.97	3.43	74.3%
May	2.66	4.45	67.4%
Jun	3.85	5.63	46.1%
Jul	4.56	6.81	49.4%
Aug	5.13	7.84	52.8%
Sep	6.17	8.83	43.2%
Oct	7.15	9.92	38.9%
Nov	8.26	11.06	33.9%
Dec	9.01	11.70	29.8%

Actual energy generation of MH1 is different from the forecasted generation of the same. According to table 5.1 current model has underestimated the total annual energy by 29%. Because of the increase of design capacity to 4,000 kW from the estimated design power 3,117 kW the annual plant factor has been reduced to 24% from the estimated plant factor of 40%.

Table 5.2: Energy comparison of MH1 with criteria-2

Month	Actual generation (GWh)	Predicted generation from MH2 (GWh)	% Difference
Jan	0.64	0.73	14.8%
Feb	0.97	0.94	-3.2%
Mar	1.39	1.21	-13.1%
Apr	1.97	1.96	-0.1%
May	2.66	2.59	-2.7%
Jun	3.85	4.29	11.4%
Jul	4.56	5.36	17.6%
Aug	5.13	6.34	23.6%
Sep	6.17	7.83	27.0%
Oct	7.15	9.72	36.0%
Nov	8.26	11.55	39.8%
Dec	9.01	12.96	43.8%

According to criteria-2, energy generation of MH1 is predicted based on the performance of MH2 situated downstream to MH1 but in the same catchment. Here actual energy generation of MH2 corresponding to unit catchment area and unit head is assumed as same for the upstream power plant. According to the results shown in table 5.2, total annual energy potential is over estimated by 43% from this criteria.

Criteria-3 shown in table 5.3 illustrates the fact it underestimates total energy of MH1 by 10% while criteria-4 shown in table 5.4 it overestimates energy potential of the site by 51%. In contrast with above four criteria, 2^{nd} criteria gives a very accurate energy estimation which is under estimated by only 2% of annual energy potential up to 5 months of the year.

Table 5.3: Energy comparison of MH1 with criteria-3

Month	Actual generation (GWh)	Predicted generation from MH3 (GWh)	% Difference
Jan	0.64	0.40	-36.7%
Feb	0.97	0.69	-28.7%
Mar	1.39	1.03	-25.8%
Apr	1.97	1.69	-14.1%
May	2.66	2.31	-13.1%
Jun	3.85	3.24	-15.8%
Jul	4.56	4.08	-10.6%
Aug	5.13	4.63	-9.7%
Sep	6.17	5.41	-12.2%
Oct	7.15	6.23	-12.8%
Nov	8.26	7.21	-12.8%
Dec	9.01	8.07	-10.5%

Table 5.4: Energy comparison of MH1 with criteria-4

Month	Actual generation (GWh)	Predicted generation from MH4 (GWh)	% Difference
Jan	0.64	0.94	47.3%
Feb	0.97	1.35	39.5%
Mar	1.39	2.20	57.6%
Apr	1.97	3.08	56.9%
May	2.66	4.03	51.5%
Jun	3.85	5.60	45.3%
Jul	4.56	7.06	54.9%
Aug	5.13	7.93	54.5%
Sep	6.17	9.27	50.3%
Oct	7.15	10.53	47.4%
Nov	8.26	12.49	51.2%
Dec	9.01	13.65	51.4%

Tables 5.5 thru 5.8 illustrates the comparison of actual energy generation data of MH2 with different criteria of forecasting.

Table 5.5: Energy comparison of MH2 with criteria-1

Month	Actual generation (GWh)	Predicted generation by SEA model (GWh)	% Difference
Jan	0.35	0.41	17.5%
Feb	0.44	0.87	96.1%
Mar	0.57	1.40	144.6%
Apr	0.92	1.91	107.0%
May	1.22	2.35	92.9%
Jun	2.02	2.73	34.9%
Jul	2.53	3.21	27.2%
Aug	2.99	3.63	21.6%
Sep	3.69	4.04	9.4%
Oct	4.58	4.54	-0.8%
Nov	5.44	4.93	-9.4%
Dec	6.11	5.31	-13.1%

Actual energy generation of MH2 is different from the generation forecasted by the current model where about 13% of energy potential is under estimated as shown in table 5.5. According to same, the design capacity has been increased to 3,000 kW from the estimated value of 1,980 kW which led to decrease of plant factor to 22% from the recommended value of 40%.

Table 5.6: Energy comparison of MH2 with criteria-2

Month	Actual generation (GWh)	Predicted generation from MH1 (GWh)	% Difference
Jan	0.35	0.30	-12.9%
Feb	0.44	0.46	3.3%
Mar	0.57	0.66	15.1%
Apr	0.92	0.93	0.1%
May	1.22	1.25	2.8%
Jun	2.02	1.82	-10.3%
Jul	2.53	2.15	-15.0%
Aug	2.99	2.42	-19.1%
Sep	3.69	2.91	-21.3%
Oct	4.58	3.37	-26.5%
Nov	5.44	3.89	-28.5%
Dec	6.11	4.25	-30.5%

According to criteria-2, energy generation of MH2 is predicted based on the performance of MH1 situated upstream to MH2 which is situated in the same catchment. According to the results shown in table 5.6, total annual energy potential is under estimated by 30% from this criteria, but it gives very accurate estimate for first 5 month which only over estimates by 2%.

Table 5.7: Energy comparison of MH2 with criteria-3

Month	Actual generation (GWh)	Predicted generation from MH3 (GWh)	% Difference
Jan	0.35	0.19	-44.8%
Feb	0.44	0.33	-26.3%
Mar	0.57	0.49	-14.6%
Apr	0.92	0.80	-14.0%
May	1.22	1.09	-10.7%
Jun	2.02	1.53	-24.5%
Jul	2.53	1.92	-24.0%
Aug	2.99	2.18	-27.0%
Sep	3.69	2.55	-30.9%
Oct	4.58	2.94	-35.9%
Nov	5.44	3.40	-37.6%
Dec	6.11	3.80	-37.8%

About 30% of under estimation is resulted by Criteria-3 shown in table 5.7 while criteria-4 shown in table 5.8 overestimates energy potential of the site by 5%. In contrast with above four criteria, 2nd criteria gives a very accurate energy estimation which is over estimated by only 2% of annual energy potential up to 5 months of the year.

Table 5.8: Energy comparison of MH2 with criteria-4

Month	Actual generation (GWh)	Predicted generation from MH4 (GWh)	% Difference
Jan	0.35	0.44	28.3%
Feb	0.44	0.64	44.2%
Mar	0.57	1.04	81.5%
Apr	0.92	1.45	57.1%
May	1.22	1.90	55.7%
Jun	2.02	2.64	30.4%
Jul	2.53	3.33	31.7%
Aug	2.99	3.73	25.0%
Sep	3.69	4.37	18.3%
Oct	4.58	4.96	8.4%
Nov	5.44	5.89	8.2%
Dec	6.11	6.43	5.3%

Tables 5.9 thru 5.12 illustrates the comparison of actual energy generation data of MH3 with different criteria of forecasting.

Table 5.9: Energy comparison of MH3 with criteria-1

Month	Actual generation (GWh)	Predicted generation by SEA model (GWh)	% Difference
Jan	0.61	0.89	46.2%
Feb	1.04	1.83	76.4%
Mar	1.55	2.95	90.5%
Apr	2.53	4.46	76.4%
May	3.46	6.21	79.6%
Jun	4.85	7.72	59.1%
Jul	6.10	9.29	52.3%
Aug	6.93	10.66	53.9%
Sep	8.10	12.30	51.9%
Oct	9.32	14.21	52.5%
Nov	10.78	15.60	44.7%
Dec	12.07	16.72	38.6%

Actual energy generation of MH3 is also different from the generation forecasted by the current model where about 38% of energy potential is over estimated as shown in

table 5.9. Plant factor of the project has been increased to 42% as the design capacity decreased to 3,200 kW from the estimated value of 4,278 kW according to the current model.

Table 5.10: Energy comparison of MH3 with criteria-2

Month	Actual generation (GWh)	Predicted generation from MH1(GWh)	% Difference
Jan	0.61	0.96	57.9%
Feb	1.04	1.45	40.2%
Mar	1.55	2.09	34.8%
Apr	2.53	2.94	16.4%
May	3.46	3.98	15.0%
Jun	4.85	5.76	18.8%
Jul	6.10	6.82	11.9%
Aug	6.93	7.67	10.8%
Sep	8.10	9.22	13.9%
Oct	9.32	10.69	14.7%
Nov	10.78	12.36	14.6%
Dec	12.07	13.48	11.8%

According to criteria-2, energy generation of MH3 is predicted based on the performance of MH1 situated upstream to MH3 which is situated in the same catchment. According to the results shown in table 5.10, total annual energy potential is over estimated by 11% from this criteria.

Table 5.11: Energy comparison of MH3 with criteria-3

Month	Actual generation (GWh)	Predicted generation from MH2(GWh)	% Difference
Jan	0.61	1.10	81.3%
Feb	1.04	1.41	35.7%
Mar	1.55	1.81	17.1%
Apr	2.53	2.94	16.2%
May	3.46	3.87	11.9%
Jun	4.85	6.42	32.4%
Jul	6.10	8.02	31.6%
Aug	6.93	9.49	37.0%
Sep	8.10	11.72	44.6%
Oct	9.32	14.54	56.0%
Nov	10.78	17.28	60.3%
Dec	12.07	19.39	60.7%

Criteria-3 shown in table 5.11 illustrates the fact it over estimates total energy of MH3 by 60% while criteria-4 shown in table 5.12 also overestimates energy potential of the site by 69%. In contrast with above four criteria, 3rd criteria gives comparatively accurate energy estimation with a accuracy of 11% over estimation up to first 5 months while 11% overestimation resulted with 2nd criteria for entire year.

Table 5.12: Energy comparison of MH3 with criteria-4

Month	Actual generation (GWh)	Predicted generation from MH4(GWh)	% Difference
Jan	0.61	1.41	132.6%
Feb	1.04	2.03	95.6%
Mar	1.55	3.29	112.4%
Apr	2.53	4.61	82.7%
May	3.46	6.02	74.3%
Jun	4.85	8.37	72.6%
Jul	6.10	10.57	73.3%
Aug	6.93	11.86	71.2%
Sep	8.10	13.86	71.2%
Oct	9.32	15.75	69.0%
Nov	10.78	18.69	73.3%
Dec	12.07	20.41	69.2%

Tables 5.13 thru 5.16 illustrates the comparison of actual energy generation data of MH4 with different criteria of forecasting.

Actual energy generation of MH4 is different from the generation forecasted by the current model where about 69% of energy potential is over estimated as shown in table 5.5. According to same, the design capacity has been increased to 7,200 kW from the estimated value of 5,129 kW which led to decrease of plant factor to 37% from the recommended value of 40%.

Table 5.13: Energy comparison of MH4 with criteria-1

Month	Actual generation (GWh)	Predicted generation by SEA model (GWh)	% Difference
Jan	1.63	0.95	-41.6%
Feb	2.35	2.01	-14.4%
Mar	3.81	3.33	-12.7%
Apr	5.35	5.17	-3.4%
May	6.99	6.39	-8.6%
Jun	9.72	7.35	-24.4%
Jul	12.26	8.38	-31.7%
Aug	13.76	9.33	-32.2%
Sep	16.09	10.45	-35.0%
Oct	18.28	12.20	-33.3%
Nov	21.68	13.78	-36.5%
Dec	23.69	14.95	-36.9%

According to criteria-2, energy generation of MH4 is predicted based on the performance of MH1 situated upstream to MH4 which is situated in a part of the same catchment. According to the results shown in table 5.14, total annual energy potential is under estimated by 33% from this criteria.

Table 5.14; Energy comparison of MH4 with criteria-2

Month	Actual generation (GWh)	Predicted generation from MH1 (GWh)	% Difference
Jan	1.63	1.11	-32.1%
Feb	2.35	1.69	-28.3%
Mar	3.81	2.42	-36.6%
Apr	5.35	3.41	-36.3%
May	6.99	4.61	-34.0%
Jun	9.72	6.69	-31.2%
Jul	12.26	7.92	-35.4%
Aug	13.76	8.90	-35.3%
Sep	16.09	10.70	-33.5%
Oct	18.28	12.40	-32.2%
Nov	21.68	14.34	-33.9%
Dec	23.69	15.65	-33.9%

Table 5.15: Energy comparison of MH4 with criteria-3

Month	Actual generation (GWh)	Predicted generation from MH2 (GWh)	% Difference
Jan	1.63	1.27	-22.1%
Feb	2.35	1.63	-30.6%
Mar	3.81	2.10	-44.9%
Apr	5.35	3.41	-36.4%
May	6.99	4.49	-35.8%
Jun	9.72	7.45	-23.3%
Jul	12.26	9.31	-24.1%
Aug	13.76	11.01	-20.0%
Sep	16.09	13.59	-15.5%
Oct	18.28	16.87	-7.7%
Nov	21.68	20.05	-7.5%
Dec	23.69	22.50	-5.0%

About 5% of under estimation is resulted by Criteria-3 shown in table 5.15 while criteria-4 shown in table 5.16 under estimates energy potential of the site by 40%. In contrast with above four criteria, 3rd criteria gives a very accurate energy estimation which is under estimated by only 5% of annual energy potential for entire year.

Table 5.16: Energy comparison of MH4 with criteria-4

Month	Actual generation (GWh)	Predicted generation from MH3 (GWh)	% Difference
Jan	1.63	0.70	-57.0%
Feb	2.35	1.20	-48.9%
Mar	3.81	1.80	-52.9%
Apr	5.35	2.93	-45.3%
May	6.99	4.01	-42.6%
Jun	9.72	5.63	-42.1%
Jul	12.26	7.08	-42.3%
Aug	13.76	8.04	-41.6%
Sep	16.09	9.40	-41.6%
Oct	18.28	10.82	-40.8%
Nov	21.68	12.51	-42.3%
Dec	23.69	14.00	-40.9%

6. CONCLUSION AND RECOMMENDATIONS

In this study an analysis of average monthly energy generation of mini hydro power plants situated in a same catchment and in a row is carried out. A new criteria for estimating average monthly energy potentials of a catchment where an existing power plants are being operated is proposed by the new criteria. Energy generation is derived by using measured rainfall data from 2004 to 2014 obtained from meteorological department of Sri Lanka and actual performance data of operational mini hydro power plants of the same catchment. It is developed a polynomial correlation to estimate the energy potential variation with the month. The derived correlation shows a better correlation of energy generation up to 5 months of the year.

The difference of estimated monthly average energy potentials with the current model varies between 2 to 11% when energy generation is estimated using performance data of nearest up stream operational mini hydro scheme which should be situated within 5 km of weir to weir distance and in the same catchment. Estimated energy potentials vary more than above percentage differences if the operational power plant which being referred for estimating the energy potential of down stream power plant is situated in a different catchment and more than 5 km weir to weir distance.

As the current energy estimation model produces annual energy generation potentials with 13-36% higher deviations it can be recommended to use the proposed model for estimating energy potentials for only 5 months as it produces more accurate estimation. Further to this, it can be used only for estimating down stream schemes as it produces more deviations when forecasting energy potentials of up stream schemes.

As future works, it is necessary to validate the proposed energy estimation criteria with other catchments belong to different climatic zones of Sri Lanka in future. Further it is required to research on the estimation of energy potentials of catchments

having variations of catchment characteristics since in this research only one catchment is focused and it is assumed that catchment characteristics does not vary with the considered project areas. So it is required to plan a customized method to estimate the hydraulic energy potential of selected mini hydro schemes which accounts catchment properties and project technical parameters in the future.

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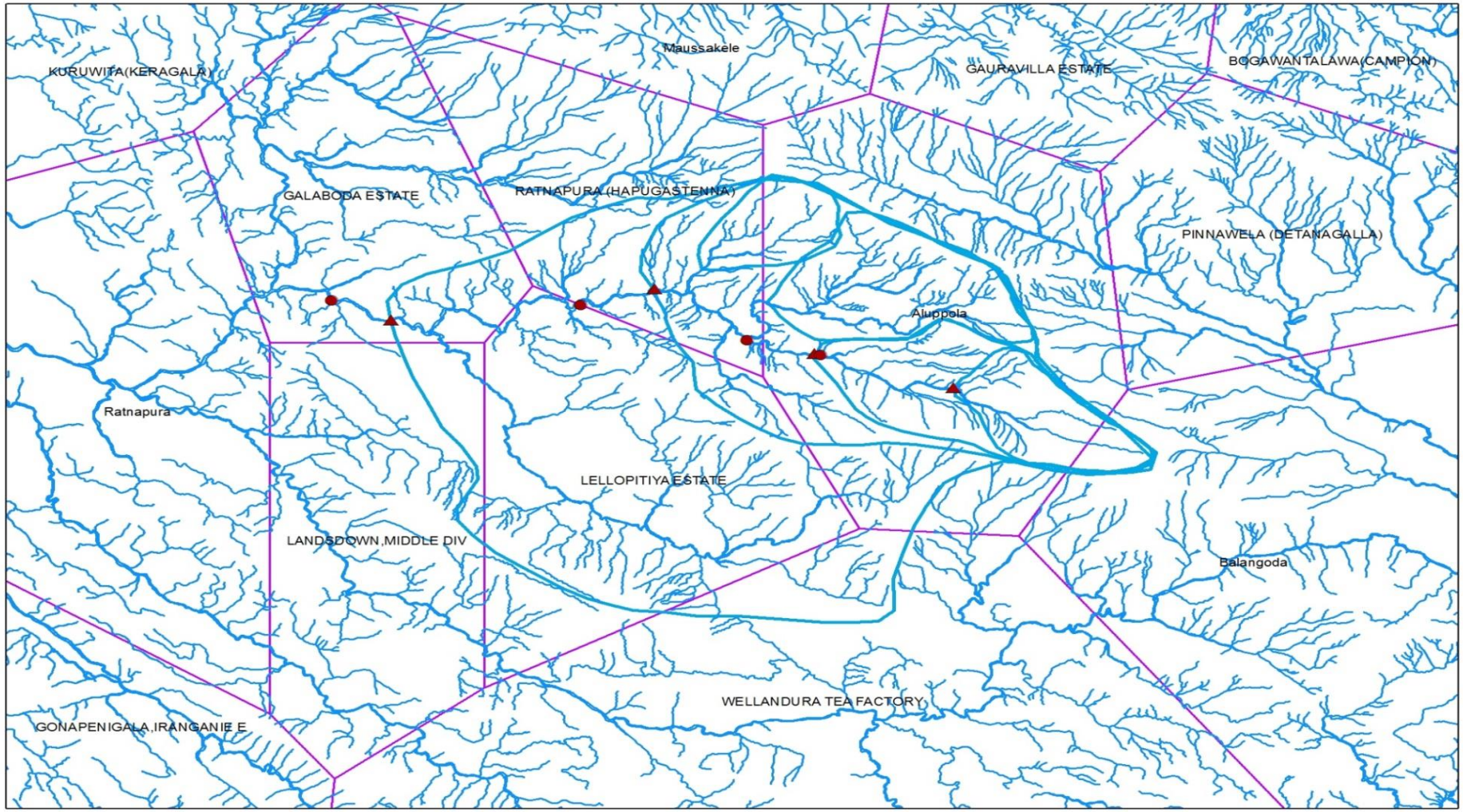
APPENDIX A: Catchments of selected mini hydro power plants

APPENDIX B: Annual average rainfalls

APPENDIX C: Sensitivity Analysis

APPENDIX A: Catchments of mini hydro power plants



District	Station	Lon	Lat	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Badulla	ALUTHNUWARA	81.00	7.32	423.71	159.76	80.57	132.92	61.48	18.13	29.55	45.42	56.21	242.16	477.85	447.97
Badulla	BANDARAELIYA ESTATE	81.02	6.79	171.78	119.22	196.45	344.67	156.23	47.51	50.96	76.89	166.25	373.26	385.33	212.88
Badulla	BADULLA (DEBEDDE)	81.12	6.96	230.59	111.35	120.90	267.18	118.54	105.28	73.03	108.57	146.73	295.73	347.69	289.65
Badulla	ELLA (KINNELAN ESTATE)	81.05	6.87	131.39	77.68	96.71	246.76	132.38	70.34	64.54	101.17	139.97	283.46	278.74	202.37
Badulla	KANDAKETIYA	81.02	7.17	417.12	189.67	66.12	109.16	50.81	16.58	18.45	41.55	42.65	156.58	343.62	405.27
Badulla	BADULLA(KEENAKELLE)	81.02	7.05	347.44	143.10	99.00	158.88	79.79	30.45	44.33	61.75	71.83	189.33	346.48	351.93
Badulla	GALINDA(LEDGE RWATTE)	81.02	7.03	451.23	170.82	128.67	220.27	93.86	38.98	35.02	52.81	78.47	171.52	381.42	427.63
Badulla	LOWER SPRING VALLEY	81.10	6.92	246.37	124.73	175.95	296.66	135.18	86.08	78.35	130.63	157.51	317.33	358.38	348.88
Badulla	MADULSIMA (MAHADOWA)	81.17	7.02	303.75	160.22	173.78	285.45	119.02	57.45	69.30	103.06	135.78	325.33	384.33	328.63
Badulla	NARANGALLA(BADULLA)	81.00	7.05	450.56	174.39	118.96	247.67	96.21	39.38	31.98	73.72	112.22	231.41	411.72	381.01
Badulla	BATHGODA-HALDUMMULLA	80.90	6.77	147.30	166.12	254.78	464.51	158.83	28.10	26.72	58.85	106.00	402.65	472.24	258.31
Badulla	BEAUVAIS ESTATE	80.90	6.79	135.94	90.29	137.58	301.69	150.08	39.68	41.84	66.14	118.85	357.19	343.11	263.46
Badulla	BOGAHAMADITTA	81.05	6.97	175.66	71.93	79.06	156.95	107.49	50.72	46.62	88.55	89.56	221.88	275.49	207.93
Badulla	KAHAGAL	80.97	6.79	136.32	83.06	126.20	224.06	110.98	34.98	43.71	64.23	161.22	308.35	283.71	182.12
Badulla	RANTEMBE	80.95	7.21	444.82	178.17	100.13	111.58	41.33	16.26	11.72	33.56	33.20	142.71	372.81	434.63
Badulla	MICKLEFIELD FARM	80.90	6.86	126.49	69.64	80.28	194.89	101.93	46.88	47.53	61.21	112.51	219.82	243.05	147.01
Badulla	DAMBATENNE	81.01	6.79	177.51	134.71	248.68	389.21	188.46	39.77	48.19	106.59	170.31	464.53	505.32	281.14
Badulla	DIVULAPELLESSA	80.98	7.58	262.07	105.75	76.80	78.55	41.46	2.22	23.15	46.88	35.73	156.85	293.21	362.51
Badulla	DIYATALAWA-SURCAMP	80.79	6.82	117.72	59.88	96.45	196.92	99.18	49.20	54.19	60.44	130.63	254.92	258.63	163.40
Badulla	GIRANDURUKOTTE	81.09	7.46	307.45	139.32	58.94	123.41	38.18	19.17	33.65	32.01	49.96	116.30	295.46	312.86
Badulla	GLEN ALPIN ESTATE	81.08	6.96	213.94	103.70	81.85	209.57	112.84	54.36	66.38	100.28	146.57	229.27	310.61	219.22
Badulla	GONAMOTAVA	80.98	6.80	155.51	90.77	142.72	251.43	95.88	33.80	34.06	42.03	116.89	290.86	269.24	180.06

Badulla	HAPUTALE FACTORY	80.96	6.78	155.76	110.90	186.97	352.89	139.53	43.21	50.58	72.67	153.52	348.14	378.71	251.37
Badulla	HEMBARAWA	80.97	7.53	270.31	125.20	53.84	90.43	25.70	3.99	29.77	35.37	46.56	148.82	292.09	300.04
Badulla	HILPANKANDURA ESTATE	80.15	7.52	130.80	84.79	57.07	161.26	138.87	62.02	68.51	74.95	122.15	280.42	330.59	224.19
Badulla	MAPAKADAWEWA	81.03	7.27	429.49	211.03	70.28	167.83	66.24	16.21	29.49	56.42	81.88	251.01	475.90	437.85
Badulla	NAYABEDDE	80.00	6.80	165.43	103.55	179.26	297.75	119.45	37.79	48.40	59.89	152.31	320.75	322.25	238.47
Badulla	POONAGALA, PG DIVISION	81.05	6.78	151.15	158.92	248.02	351.44	158.35	35.33	39.35	42.77	176.14	447.43	483.46	212.55
Badulla	POONAGALA, LLG DIV	81.04	6.78	171.07	155.14	259.56	379.35	187.53	54.91	47.20	63.19	172.65	398.07	521.03	229.67
Badulla	POONAGALA, CG DIVISION	81.05	6.76	161.62	166.68	270.41	366.53	192.34	57.11	43.59	55.96	190.17	445.74	496.85	230.35
Badulla	POONAGALA, BTN DIV	81.05	6.80	183.49	124.83	252.43	346.32	210.81	35.92	51.75	42.45	182.40	380.04	492.77	286.51
Badulla	POONAGALA, ULG DIV	81.05	6.79	175.96	125.25	274.06	373.73	167.32	57.47	57.33	65.12	179.61	451.64	504.82	240.18
Badulla	POONAGALA, UH DIVISION	81.06	6.76	162.87	164.40	300.40	352.94	194.35	55.23	40.79	50.74	147.70	439.51	481.61	239.48
Badulla	ST.CATHERINE DIVISION	81.02	6.80	155.30	98.17	218.98	300.72	105.86	34.56	55.67	59.81	146.10	307.57	336.58	233.18
Badulla	WELIMADA(WELIA GR.)	80.90	6.90	146.28	73.74	59.89	152.36	103.87	47.48	35.43	75.46	123.43	159.62	205.75	155.87
Badulla	WEST HAPUTALE-UDAVERIYA	80.83	6.78	156.36	136.09	194.80	383.45	113.11	54.46	47.37	64.73	124.71	323.28	399.76	274.84
Badulla	WEWESSA ESTATE	81.11	6.97	210.19	107.58	105.21	228.02	130.64	79.41	70.08	103.69	131.45	261.08	308.02	274.95
Badulla	WEWESSEMIDDLE DIVISION	81.10	6.96	149.66	61.20	106.78	137.38	53.63	27.97	57.47	57.39	88.65	157.20	198.31	175.91
Badulla	BADULLA(METEO)	81.05	6.98	211.79	92.18	81.55	183.31	98.06	52.98	51.33	82.78	110.83	232.07	291.97	245.62
Colombo	PUWAKPITIYA (AV-WELLA E)	80.18	6.92	176.85	125.96	173.94	405.50	350.12	276.02	278.64	218.55	392.23	458.20	429.62	222.50
Colombo	DEHIWALAZOO	79.80	6.85	88.15	85.62	82.31	260.70	248.94	135.82	145.26	100.06	228.21	367.12	327.08	160.75
Colombo	LABUGAMA TANK	80.10	6.83	165.82	156.53	190.58	471.12	384.97	315.82	296.70	247.90	397.29	582.95	463.91	245.32
Colombo	ORUWALA	80.00	6.88	103.41	71.60	90.89	244.53	321.12	126.60	198.76	150.23	326.46	467.04	299.28	190.48
Colombo	HOMAGAMA	80.02	6.83	158.93	85.12	129.62	306.66	344.78	242.62	215.22	210.06	294.58	520.17	426.58	218.58
Colombo	PADUKKA ESTATE	80.12	6.82	147.19	131.34	140.41	404.75	366.93	297.42	245.19	227.73	331.78	546.45	451.19	273.22

Colombo	PITIPANA	80.03	6.76	130.67	75.56	74.97	287.51	298.22	174.91	210.21	186.30	329.06	431.70	373.76	221.89
Colombo	S.L. PORTS AUTTY	79.85	6.93	63.34	44.74	80.34	208.63	230.87	118.87	107.94	141.25	215.00	345.73	300.09	113.59
Galle	BEAUSEJOUR(LOWER)	80.33	6.15	139.02	137.07	166.01	291.05	314.59	217.45	194.03	209.17	376.49	402.99	285.02	216.26
Galle	DEVITURAI ESTATE	80.16	6.26	181.43	107.27	155.58	301.05	401.88	279.26	263.17	205.42	431.83	572.39	367.77	268.35
Galle	HINIDUMA	80.32	6.31	203.53	196.53	240.59	411.18	457.31	313.58	341.51	259.41	493.23	603.08	417.58	307.69
Galle	MONROVIA GROUP	80.15	6.08	70.19	67.68	86.73	143.86	173.87	121.72	128.39	102.54	216.07	264.98	179.05	142.86
Galle	TITAGALLA, HANDUNGODA	80.36	6.02	126.88	103.46	111.15	255.54	260.07	191.97	211.26	153.86	257.23	391.19	266.70	217.00
Hamban	BATA ATA	80.92	6.10	72.76	65.54	68.75	95.22	77.36	47.62	35.28	56.93	109.55	156.78	205.72	135.84
Hamban	BUNDALA LEWAYA	81.25	6.20	95.25	56.32	44.19	95.30	55.68	25.35	28.36	38.32	60.08	140.62	274.78	134.58
Hamban	LIYANGAHATOTA	80.93	6.23	79.11	68.75	89.45	143.35	59.04	30.94	28.63	27.28	71.35	135.10	279.45	132.75
Hamban	BADAGIRIYA TANK	81.15	6.23	67.08	52.92	70.17	110.39	38.05	9.42	17.42	31.61	37.81	120.41	255.17	130.74
Hamban	MAHA LEWAYA (HAMBANTOTA)	81.13	6.13	78.97	49.32	50.75	92.96	50.05	26.68	19.14	37.97	73.87	105.72	243.46	91.48
Hamban	MAMADOLA	80.98	6.15	80.37	64.14	66.88	109.15	65.08	36.88	35.87	38.56	92.77	140.77	229.24	121.04
Hamban	PALATUPANA SALTERN	81.38	6.25	106.84	55.91	58.32	91.23	35.99	18.38	13.64	20.32	43.04	116.04	238.75	168.42
Hamban	RIDIYAGAMA IRRIGATION	80.98	6.22	73.09	67.46	79.77	139.08	57.75	26.72	19.28	27.72	71.77	134.12	249.36	117.95
Hamban	TANGALLA	80.80	6.02	53.52	44.22	33.07	84.32	83.34	67.50	57.13	61.38	160.51	182.44	143.07	85.23
Hamban	TISSAMAHARAMA IRRIGATION	81.30	6.28	128.12	68.95	44.78	107.87	31.84	17.11	14.58	33.11	48.05	162.28	280.15	188.41
Hamban	LUNUGAMWEHERA	81.20	6.33	93.00	78.35	75.85	140.48	41.40	18.55	13.41	38.11	46.25	167.45	305.85	150.67
Hamban	MURUTHAWELA WEWA	80.73	6.21	110.00	110.27	96.95	186.50	91.15	46.30	54.57	49.77	89.97	204.98	272.88	165.65
Hamban	RIDIYAGAMA IRRIGATION	80.97	6.19	71.83	54.37	65.58	116.34	60.38	22.90	31.65	31.55	77.28	119.46	249.85	126.47
Kaluthara	BANDARAGA	80.08	6.72	132.97	93.84	96.01	278.02	322.00	239.30	181.73	199.53	310.78	487.21	352.95	203.03
Kaluthara	HORANA	80.07	6.75	152.88	122.94	167.44	312.76	393.63	280.22	194.14	185.98	365.70	631.19	345.08	242.35
Kaluthara	KALUTARA_P.W.D	79.95	6.58	112.54	106.02	141.74	242.48	304.79	188.84	170.62	171.16	257.30	448.26	310.40	162.58

Kaluthara	ARAMANAGOLLA	80.06	6.73	194.18	134.09	145.22	354.34	394.58	287.65	258.38	239.75	391.10	569.48	421.03	219.82
Kaluthara	MILLEWA ESTATE	80.08	6.80	157.60	116.98	145.81	434.98	430.78	323.43	265.31	255.97	380.07	580.78	508.18	248.24
Kaluthara	RAYIGAMA	80.18	6.77	147.03	152.22	174.57	369.34	351.56	282.54	228.32	237.33	339.73	458.91	394.69	216.93
Kaluthara	SIRIKANDURA ESTATE	80.15	6.50	189.88	142.74	210.36	361.37	474.78	318.35	263.79	251.35	457.94	623.70	320.55	268.68
Kaluthara	ST.GEORGES GROUP	80.12	6.52	181.07	140.92	93.37	316.47	395.07	256.13	272.95	231.50	465.76	479.88	260.48	243.63
Kaluthara	DEDIYAWALA-WASKADUWA	79.95	6.62	51.48	64.94	28.06	201.22	218.10	106.50	115.26	65.58	181.73	404.67	207.05	172.90
Kaluthara	HORAGODA ESTATE	80.25	6.50	167.58	161.72	199.08	422.91	429.87	316.42	321.08	239.97	464.92	602.14	388.46	301.44
Kaluthara	MORAPITIY	80.27	6.53	231.67	187.25	251.18	422.48	499.93	365.69	334.17	324.45	471.96	616.99	393.84	349.13
Kaluthara	PALLEGODA ESTATE	80.05	6.47	179.96	121.75	138.35	320.02	452.95	252.47	178.74	191.63	316.68	569.40	323.13	168.44
Kaluthara	PELAWATTE	80.22	6.42	223.39	216.17	268.94	382.32	468.24	312.19	319.58	269.65	466.52	589.99	415.18	309.82
Kaluthara	PERTH ESTATE	80.12	6.72	161.91	166.44	139.49	411.05	441.32	276.30	232.77	252.02	403.43	564.93	394.99	272.92
Kaluthara	USK VALLEY S.P	80.23	6.57	212.74	165.68	273.82	398.92	497.54	282.27	350.62	317.47	508.27	596.57	380.15	359.08
Kaluthara	KALUTARA,VOGAN GROUP	80.10	6.54	166.96	120.78	154.38	342.88	526.63	320.95	274.32	229.42	423.15	562.85	335.75	221.80
Kandy	RANGALA	80.78	7.35	239.03	93.87	111.10	225.71	102.98	150.32	134.81	122.92	155.78	302.88	292.58	268.93
Kandy	WATTEGAMA (GALPHELPHELE)	80.70	7.35	133.40	74.78	97.38	195.22	100.23	127.55	141.43	102.77	187.78	294.34	268.18	217.48
Kandy	DOLOSBAGE (KELLIE)	80.43	7.12	60.52	194.10	100.13	591.05	266.90	74.10	439.25	307.63	65.28	691.15	122.40	299.80
Kandy	KOBONELLA ESTATE	80.85	7.35	531.25	302.88	102.29	310.39	90.08	120.95	105.00	155.57	148.33	378.79	265.53	422.07
Kandy	KUNDASALE FARM	80.68	7.27	84.35	53.88	93.33	163.02	63.88	75.08	43.53	50.35	78.85	177.80	196.23	156.78
Kandy	NAWALAPITIYA	80.53	7.07	81.95	71.93	111.49	281.78	241.33	323.62	327.78	270.95	336.25	396.96	282.72	118.55
Kandy	GALAHA(NEW FOREST)	80.68	7.15	227.72	122.83	110.65	298.42	149.56	156.18	160.46	128.09	200.71	314.58	338.32	234.30
Kandy	PERADENIYA BOT.GARDENS	80.60	7.27	61.04	59.45	119.74	213.66	123.35	114.31	110.05	85.35	116.54	245.40	247.33	143.76
Kandy	PUSSELLAWA (SOGAMA)	80.62	7.12	90.97	85.60	118.70	331.68	182.65	159.82	220.85	188.36	236.26	326.84	297.93	150.71
Kandy	WOODSIDE ESTATE	80.83	7.27	194.55	113.31	69.68	208.34	76.87	46.60	47.19	43.42	92.47	257.50	242.91	251.74

Kandy	POLGOLLA	80.62	7.32	98.24	76.42	167.62	208.63	88.43	110.42	92.48	70.14	127.10	243.17	232.62	174.78
Kandy	KOTHMALE POWERTION	80.57	7.12	96.30	70.18	114.87	270.20	135.09	224.95	243.25	204.05	253.30	301.97	262.48	134.25
Kandy	RANDENIGALA	80.57	7.10	377.81	150.80	73.85	127.48	39.54	11.68	14.37	27.99	53.13	149.07	338.84	397.36
Kandy	KOTHMALE POWER ST	80.58	7.02	71.04	74.75	129.99	237.13	137.77	131.45	118.76	96.22	142.97	233.05	235.63	106.74
Kandy	DOLOSBAGE,INGURUGOLLA	80.46	7.12	116.52	101.60	119.88	327.51	279.46	305.42	345.14	241.13	348.18	432.98	334.78	177.11
Kandy	DELTA ESTATE,EAST DIV	80.67	7.12	150.65	80.19	113.57	324.87	168.18	202.48	231.71	175.72	215.24	349.16	316.65	181.04
Kandy	DELTA ESTATE,SOUTH DIV	80.65	7.10	128.18	73.08	117.80	288.23	178.32	202.86	214.59	171.67	230.52	317.19	239.34	163.44
Kegall	ALAGALLA	80.48	7.28	117.65	85.28	134.48	267.43	299.15	118.68	216.50	116.93	279.80	310.07	351.35	297.70
Kegall	ARANAYAKE GOVT	80.47	7.18	60.96	60.41	127.36	219.30	126.57	111.93	159.22	89.18	177.40	274.89	259.91	112.27
Kegall	Batalagoda Tank	80.45	7.52	94.08	60.25	87.52	211.60	120.03	77.63	63.84	53.57	80.61	323.72	268.75	164.92
Kegall	CHESTERFORD	80.18	7.07	142.66	125.75	192.38	410.53	344.98	294.44	225.25	201.90	383.45	559.87	436.19	198.02
Kegall	DEHIOWITA (DIGALLA)	80.30	6.95	128.78	150.95	224.11	450.97	445.10	351.10	317.95	278.65	357.25	553.44	431.78	185.14
Kegall	DEHIOWITA (DUNEDIN)	80.28	7.03	132.74	132.92	205.52	410.01	373.14	260.28	262.72	198.72	389.74	512.14	343.19	165.21
Kegall	Frocester Estate	80.12	6.67	159.26	171.23	145.95	400.25	462.53	294.48	279.00	280.02	441.42	486.89	367.44	265.29
Kegall	MALIBODA	80.43	6.88	110.18	113.88	239.75	473.48	530.75	464.47	475.44	395.75	516.97	597.40	385.39	239.50
Kegall	UNDUGODA	80.37	7.13	106.08	87.89	200.37	358.58	323.49	301.67	293.55	206.48	338.33	413.27	369.06	154.88
Kegall	WAHARAKA(VINCIT)	80.22	7.08	124.82	114.30	224.02	418.32	354.71	263.11	243.12	179.36	361.47	549.94	426.53	161.72
Kegall	YATIYANTOTA (WEWELTALAW)	80.38	7.05	129.50	149.55	200.22	502.65	469.62	475.40	441.34	370.57	525.75	660.65	439.44	190.37
Kegall	YOGAMA ESTATE	80.27	6.92	101.88	175.88	193.57	413.15	354.26	344.78	307.19	257.60	418.84	448.05	398.00	129.90
Kegall	GOKARELLA	80.48	7.60	48.95	74.32	53.37	135.40	95.61	27.21	19.17	41.38	60.19	235.73	151.24	72.52
Kegall	MATHEMAGODA (COCONUT)	80.50	7.60	132.51	103.42	188.56	400.76	365.70	300.02	274.29	181.55	360.30	490.55	379.67	170.61
Kuru	ANDIGAMA	80.12	7.37	58.03	73.26	139.45	281.31	173.31	124.78	92.68	75.88	156.33	379.72	288.30	94.05
Kuru	KAMALASRAM (UDUBADDAWA)	79.98	7.48	36.80	49.87	112.55	215.25	170.92	106.97	79.85	76.22	155.58	405.80	305.56	110.71

Kuru	ATHARAGALLA	80.29	7.92	43.31	29.88	57.66	136.89	46.97	13.58	13.78	31.41	66.32	217.95	266.58	120.09
Kuru	HAKWATUNA OYA	80.38	7.65	69.93	77.15	62.10	214.20	93.40	28.07	49.00	24.39	102.11	292.90	240.77	161.35
Kuru	KOULWEWA	79.93	7.53	39.79	43.83	77.90	165.33	149.15	89.84	70.39	45.22	109.10	342.48	282.00	98.65
Kuru	MEDIYAWA TANK	80.28	7.88	76.94	45.58	119.28	228.48	84.79	25.99	35.58	32.83	78.90	274.83	250.84	157.04
Kuru	PATHREGALLA ESTATE	80.35	7.38	83.38	104.40	101.73	268.65	265.30	128.27	133.96	110.62	234.08	363.72	227.50	159.38
Kuru	RIDIBENDIELA	80.25	7.73	49.31	50.46	104.40	218.57	70.89	40.65	32.76	24.20	57.58	329.01	233.91	113.44
Kuru	WARIYAPOLA EXPTL.STATION	80.25	7.63	68.43	55.44	92.78	256.76	109.68	64.15	69.11	55.26	116.13	329.29	254.80	138.40
Kuru	DAMPELLASSA -NARAMMALA	80.20	7.42	71.17	65.67	152.38	268.08	149.22	107.41	72.75	83.58	189.07	393.04	303.98	83.53
Kuru	DELHENA	80.55	7.52	115.47	88.19	96.30	238.50	93.09	93.51	83.23	67.16	120.67	314.23	348.43	181.41
Kuru	HINDAWA ESTATE	80.21	7.54	37.48	57.09	128.14	252.21	117.92	90.78	71.48	56.12	137.25	367.46	302.88	117.11
Kuru	KANAMEEWALA ESTATE	80.16	7.30	74.87	76.16	102.69	389.21	209.23	126.33	124.81	82.19	248.53	385.11	263.79	92.74
Kuru	MAHAGALKADAWLA,GALGAMUWA	80.28	8.07	80.48	53.53	72.08	222.76	55.58	17.84	27.71	33.05	74.83	232.92	289.49	162.63
Kuru	MARANDAWILA FARM	79.96	7.63	55.91	45.96	84.69	178.33	129.39	59.69	52.69	40.30	94.69	285.48	231.42	90.75
Kuru	PANDUWASNUWARA	80.12	7.60	25.92	31.07	89.47	244.88	122.54	64.14	43.93	54.57	107.23	219.62	226.14	76.09
Kuru	POLGAHAWELA (COCONUT)	80.31	7.33	53.89	100.81	119.87	260.78	165.57	119.12	111.22	84.15	162.30	338.35	297.28	106.25
Kuru	POLONTALAWA	80.00	7.72	29.45	41.75	90.08	229.71	123.48	60.52	61.61	43.98	100.57	249.45	220.77	116.14
Kuru	SIYAMBALANGAMUWA	80.45	7.95	40.83	52.68	54.15	202.29	39.47	6.40	23.83	23.41	52.62	244.00	271.90	143.65
Kuru	THAMBANA ESTATE	79.97	7.39	40.15	47.45	67.48	196.18	157.24	93.95	73.58	78.83	141.42	346.91	216.32	69.65
Kuru	WEUDA	80.48	7.42	100.76	66.88	97.99	219.06	96.47	108.19	87.00	65.32	173.28	391.20	306.56	185.51
Matale	ELKADUWA	80.68	7.42	118.46	77.54	92.96	257.80	143.99	102.14	216.21	84.33	237.78	348.64	148.71	420.33
Matale	ILLUKKUMBURA	80.77	7.55	491.76	273.08	117.63	219.44	75.10	34.44	34.01	42.57	78.61	239.48	508.80	538.73
Matale	MATALE-P.W.D.	80.62	7.47	130.59	66.65	72.71	222.78	100.55	107.83	100.53	78.97	160.98	249.32	251.38	167.98
Matale	MILLAWANA ESTATE	80.55	7.67	157.48	97.29	76.68	216.74	94.68	69.12	54.22	54.29	88.85	325.78	294.25	229.37

Matale	NALANDAEXPER.STATION	80.63	7.67	244.52	112.62	101.26	224.42	48.74	31.65	31.85	33.59	67.85	225.06	314.17	286.40
Matale	MATALE(WARIYAPOLA E.)	80.63	7.47	159.72	75.62	73.55	231.68	94.20	93.20	84.21	68.24	137.28	228.46	257.65	166.42
Matale	DEWAHUWA	80.55	7.80	146.78	122.95	80.95	207.23	61.66	33.92	29.29	25.28	80.48	283.55	298.48	244.30
Matale	HAPPUWIDDE DIV(ELKADUWA	80.70	7.43	218.10	92.67	137.30	258.04	158.19	125.04	162.80	145.09	218.70	313.43	345.70	304.37
Matale	LOOLKADE DIVISION	80.55	7.65	142.48	86.58	67.15	203.89	84.08	62.93	57.35	49.77	88.98	326.87	269.12	216.00
Matale	UKUWELA	80.65	7.40	115.80	82.93	89.93	233.74	93.28	106.53	110.22	86.17	165.24	271.92	253.36	207.71
Matale	BOWATEN	80.67	7.67	341.62	166.55	130.61	246.82	88.78	28.23	31.99	53.54	89.54	288.04	394.16	413.62
Matale	OWELLARATTOTA	80.65	7.52	162.88	84.77	89.19	202.28	76.08	58.00	45.72	46.44	112.10	225.19	249.88	194.54
MAHA ILLUPPALLAMA		80.47	8.12	105.56	94.00	69.47	188.92	67.77	25.62	22.76	31.23	97.99	258.92	282.38	191.46
N'Eliya 1	ABERGELDIE GROUP	80.59	6.90	33.90	113.40	44.79	216.46	378.13	464.16	604.38	385.10	395.51	485.41	273.76	124.39
N'Eliya 1	AMBEWELA	80.80	6.88	148.50	74.63	81.84	171.49	116.23	194.25	162.40	147.22	166.05	211.69	248.47	166.36
N'Eliya 1	DICK OYA (ANNFIELD)	80.63	6.87	72.02	78.93	132.59	289.25	194.13	254.89	259.33	204.85	200.97	172.48	182.68	110.46
N'Eliya 1	BOPATTHALAWA	80.72	6.83	52.12	59.81	110.92	248.61	133.03	164.85	159.40	121.08	158.12	178.38	199.45	104.04
N'Eliya 1	BOGAWANTALAWA(CAMPION)	80.70	6.78	92.89	103.16	157.26	276.42	157.24	182.55	170.23	136.80	187.56	240.80	306.15	166.40
N'Eliya 1	PUNDALUOYA (DUNSINANE)	80.70	7.00	106.42	56.88	97.41	246.53	234.49	299.88	318.98	238.78	249.98	286.91	287.01	149.35
N'Eliya 1	HAKGALA(BOTANICALGDNS)	80.82	6.92	182.18	79.48	85.15	163.93	106.57	85.47	87.58	65.89	129.47	199.82	250.12	214.98
N'Eliya 1	AGRAPATANA (HOLMWOOD)	80.72	6.85	42.50	48.25	87.72	228.10	113.53	142.02	124.84	113.85	133.98	177.48	178.91	84.75
N'Eliya 1	HEWAHETA (HOPE)	80.75	7.10	384.35	155.08	131.70	259.33	128.24	178.16	153.28	136.71	182.28	271.05	388.75	422.05
N'Eliya 1	RAMBODA(LABUKELLE)	80.72	7.02	169.22	86.68	99.23	228.05	210.86	320.88	311.58	235.48	288.97	321.26	286.75	206.41
N'Eliya 1	MASKELIYA HOSPITAL	80.57	6.83	41.41	79.78	121.11	271.76	221.90	148.11	240.57	114.72	195.39	220.99	225.37	136.77
N'Eliya 1	BAMBRAKELLY -LINDULA	80.66	6.90	70.33	74.39	112.77	239.93	209.38	326.86	354.21	244.02	234.46	282.62	236.28	123.69
N'Eliya 1	NAGRAK ESTATE	80.78	6.77	88.68	138.14	215.99	371.19	109.60	88.90	65.50	65.75	106.75	248.91	317.25	208.72
N'Eliya 2	AGRAPATANA (SANDRINGHAM)	80.75	6.85	63.46	53.58	92.25	224.92	134.81	168.29	164.98	140.90	146.39	203.01	206.82	108.53

N'Eliya 2	WATAGODA	80.65	6.97	88.22	75.87	67.50	199.26	163.02	162.37	294.33	301.98	267.68	280.50	213.10	140.50
N'Eliya 2	WATAWALA	80.52	6.97	115.91	97.65	231.58	505.99	513.41	569.00	672.28	539.39	505.40	624.43	405.73	221.28
N'Eliya	DRAYTON	80.62	6.93	91.49	86.55	122.58	280.88	263.13	366.25	387.77	313.91	270.20	327.19	257.10	123.05
N'Eliya	GOONAPITIYA	80.80	7.05	383.55	139.76	184.52	272.86	118.55	81.43	88.88	95.02	116.29	275.93	432.50	389.95
N'Eliya	GAURAVILLA ESTATE	80.61	6.79	101.74	110.22	225.68	411.54	183.08	259.09	200.30	176.81	154.39	283.81	270.77	145.12
N'Eliya	HOLLY ROOD ESTATE	80.67	6.96	66.58	57.23	110.79	233.88	207.99	288.32	289.92	217.65	215.81	245.79	232.77	120.52
N'Eliya	HIGH FOREST ESTATE	80.83	7.07	354.66	145.78	130.65	250.03	125.25	103.55	70.49	100.04	132.84	251.25	335.43	359.16
N'Eliya	MARIGOLD FACTORY	80.82	7.07	302.58	123.03	114.58	161.77	93.15	49.09	39.62	64.00	91.32	180.23	282.53	291.02
N'Eliya	CANYON	80.53	6.88	74.71	93.21	132.92	301.02	365.35	501.08	564.83	395.15	412.46	433.10	282.81	124.16
N'Eliya	WIMALASURENDRA POWER STN	80.53	6.90	80.05	111.17	160.43	362.56	441.23	596.75	612.63	461.65	410.82	536.32	315.41	134.35
N'Eliya	SUMMERSET	80.70	6.93	68.82	53.03	85.06	199.86	204.14	246.98	254.67	193.78	197.60	257.34	202.33	102.05
N'Eliya	PRESIDENT S HOUSE	80.77	6.98	105.10	51.29	77.68	130.92	153.42	212.16	229.71	161.64	203.55	215.36	201.01	146.15
N'Eliya	PATTIPOLA	80.83	6.86	177.92	92.29	107.68	158.89	102.43	91.93	85.37	75.72	82.79	247.70	265.42	222.62
N'Eliya	PEDRO ESTATE	80.80	6.97	165.27	64.16	87.34	156.42	100.88	127.98	122.10	91.04	139.89	197.30	214.88	177.62
N'Eliya	PIDURUTALAGALA FARM	80.67	7.00	254.11	95.59	121.78	177.46	126.46	124.16	134.82	90.66	102.81	214.84	286.56	234.53
Rathnapura	RAKWANA(DEPEDENA)	80.55	6.47	105.35	173.76	228.52	413.83	303.32	254.17	267.35	235.94	327.49	402.65	330.25	242.98
Rathnapura	PINNAWELA (DETANAGALLA)	80.68	6.73	227.60	248.88	302.92	445.78	146.15	102.72	68.72	75.70	147.90	318.49	472.11	330.18
Rathnapura	EHELIYAGODA S.P.	80.27	6.85	138.76	153.58	259.03	466.13	431.90	345.18	300.15	261.71	465.28	578.84	397.17	222.65
Rathnapura	GONAPENIGALA,IRANGANIE E	80.33	6.57	129.26	142.03	176.92	289.50	437.71	192.04	300.41	228.30	349.99	417.10	267.20	248.10
Rathnapura	RATNAPURA (HAPUGASTENNA)	80.52	6.72	195.81	199.11	242.15	383.42	511.23	440.94	431.55	376.41	479.43	542.11	381.98	291.17
Rathnapura	ANHETTIGAMA ESTATE	80.37	6.93	122.10	133.98	192.98	436.38	448.12	396.93	369.75	298.11	466.48	537.17	329.99	166.65
Rathnapura	KALATUWAWA	80.20	6.85	164.31	166.95	200.43	483.21	398.61	345.96	318.70	259.42	413.44	564.91	460.92	235.81
Rathnapura	KURUWITA(KERAGALA)	80.36	6.80	154.72	185.72	336.09	597.92	553.63	471.75	420.35	342.19	502.48	631.75	440.03	279.88

Rathnapura	PUSSELLAS.P.	80.35	6.80	126.53	144.75	226.89	418.82	457.76	432.48	393.48	276.35	492.66	560.08	348.95	213.94
Rathnapura	BRAMPTON	80.82	6.75	140.33	182.75	280.06	500.58	119.36	44.18	17.80	43.35	112.43	305.80	433.22	260.54
Rathnapura	BELIHUL OYA UPPER DIV	80.80	6.77	109.37	114.02	206.74	309.18	100.18	63.42	35.72	59.66	139.59	316.94	333.74	194.94
Rathnapura	GALABODA ESTATE	80.47	6.70	151.10	220.78	217.81	462.33	498.83	362.88	360.29	380.67	394.06	463.06	362.29	246.08
Rathnapura	GANGEYAYA	80.83	6.38	78.64	95.38	152.75	188.63	67.03	21.22	19.44	43.62	90.39	192.19	303.45	155.65
Rathnapura	KUDAWA	80.42	6.43	164.28	163.48	272.27	475.49	533.68	368.45	375.44	343.20	486.49	543.55	387.45	305.77
Rathnapura	KUTTIGALA,CHAN DRIKAWEWA	80.90	6.25	80.11	90.33	105.80	153.18	56.22	33.85	22.93	21.25	81.48	157.24	297.51	147.45
Rathnapura	LAUDERDALE GROUP	80.62	6.42	78.97	116.97	30.63	354.03	399.57	254.09	329.30	246.69	384.43	434.03	292.58	156.83
Rathnapura	LANDSDOWN,MIDDLE DIV	80.47	6.68	102.81	141.35	195.23	321.03	408.37	360.42	318.20	305.50	361.40	502.14	350.94	206.82
Rathnapura	LELLOPITIYA ESTATE	80.50	6.68	162.32	168.19	243.81	441.51	119.13	60.38	38.17	59.42	104.77	344.92	412.46	232.52
Rathnapura	NON PAREIL (BELIHULOYA)	80.79	6.76	154.83	155.18	254.43	411.49	94.36	23.62	20.13	7.30	80.13	159.88	348.80	120.43
Rathnapura	USWEWA	80.92	6.23	46.54	78.42	75.43	143.45	228.76	219.21	203.79	220.69	249.28	275.25	321.45	232.75
Rathnapura	WELLANDURA ESTATE	80.57	6.53	108.33	197.51	205.35	252.11	229.08	202.57	183.26	175.82	236.92	283.66	290.61	205.25
Rathnapura	WELLANDURA TEA FACTORY	80.57	6.55	125.58	184.85	228.29	282.10	91.20	84.02	110.34	83.67	141.88	154.82	129.14	260.00
Badulla	Dyrabba	80.93	6.88	109.78	157.50	103.52	107.12	160.52	162.91	209.25	147.38	189.92	232.82	195.85	175.95
Badulla	Galoola	81.15	7.07	172.78	205.75	159.30	178.71	214.98	203.84	219.92	179.38	204.90	238.13	189.75	373.81
Badulla	Kirklees	80.93	6.98	169.97	208.97	191.42	187.17	170.09	194.30	226.62	112.70	257.33	215.21	293.99	432.18
Badulla	Canawerella	81.12	6.90	237.81	340.30	180.09	155.51	199.73	182.35	212.04	200.41	180.50	241.49	276.65	318.98
Galle	Baddegama	80.18	6.18	207.70	210.70	245.31	278.38	179.01	124.18	163.72	137.55	185.37	216.03	249.84	229.93
Galle	Galle	80.22	6.03	159.64	170.60	190.35	272.03	205.21	155.52	214.78	198.87	237.04	255.29	258.20	199.58
Galle	Hiyare	80.32	6.07	170.78	191.66	217.70	258.11	202.11	177.85	205.52	187.68	226.01	214.22	320.72	178.93
Galle	Labuduwa	80.23	6.07	230.85	249.92	230.99	290.48	222.38	130.15	178.54	135.79	206.23	162.60	211.22	228.19
Kalutara	Vincent	80.00	6.52	137.36	131.50	194.11	218.13	305.12	220.15	270.72	253.87	314.34	386.46	325.49	163.12

Kalutara	Neboda	80.12	6.60	228.83	305.29	312.17	334.75	353.55	343.40	381.58	381.32	519.98	424.31	207.95	205.55
Kalutara	Halwatura	80.20	6.72	265.18	262.88	196.41	413.11	223.19	183.86	261.86	222.00	244.14	295.48	268.35	264.40
Kalutara	Clyde	80.03	6.58	198.09	220.91	266.90	295.55	125.08	160.76	163.39	103.47	130.43	174.52	173.57	182.41
Kandy	Kandy	80.63	7.33	142.15	152.92	160.38	142.29	136.29	140.62	154.44	100.31	123.56	168.75	156.53	196.93
Kandy	Kandy Kin_Pavi	80.63	7.30	139.82	148.99	166.63	156.81	110.60	150.11	151.03	115.59	170.72	186.62	189.49	181.77
Kegalle	Eraminigolla	80.38	7.30	82.09	201.23	184.92	179.22	158.31	192.06	91.48	100.57	183.57	222.54	178.85	142.09
Kegalle	Ambanpitiya	80.32	7.23	170.10	246.01	254.26	240.25	135.42	137.25	147.94	104.11	150.96	209.89	166.56	118.20
Kurunegala	Kurunegala	80.35	7.77	145.60	211.46	223.28	145.35	158.73	140.52	153.19	104.92	129.27	106.99	56.02	123.73
Kurunegala	Delwita	80.52	7.53	121.13	205.67	171.09	145.18	87.48	122.85	118.54	71.65	80.89	141.01	134.79	185.72
Kurunegala	Egodagama	80.42	7.43	131.88	214.61	122.48	105.77	129.01	106.62	136.88	89.92	150.43	183.70	105.54	93.13
Kurunegala	Mellawa	79.95	7.32	119.66	155.65	177.18	222.13	98.50	114.85	120.00	72.12	95.47	149.22	138.32	91.10
Kurunegala	Nikaweratiya	80.12	7.75	75.52	149.45	120.78	140.68	101.98	95.35	107.71	71.40	114.25	138.12	113.21	127.70
Matale	Kandalama	80.68	7.87	95.06	153.65	102.34	103.00	153.25	166.73	198.46	116.65	150.19	208.89	112.42	254.58
Matale	Wiharagama	80.65	7.50	110.96	131.99	160.27	143.50	123.20	116.02	124.93	78.97	106.77	133.87	103.18	176.80
Matale	Pelwehera	80.68	7.90	121.30	164.73	112.81	102.84	136.34	81.34	175.09	139.97	141.00	195.22	178.05	234.14
Matara	Denagama	80.65	6.10	155.48	159.85	185.05	193.25	127.45	83.29	139.81	130.38	125.95	158.80	176.52	172.05
Matara	Kekenadura	80.57	5.97	105.93	131.52	137.06	184.81	147.48	133.59	136.53	101.37	137.16	181.58	170.24	129.63
N_Eliya	N_Eliya	80.77	6.97	171.65	163.45	164.30	150.11	231.96	265.86	244.02	217.48	206.52	181.81	136.67	168.60
N_Eliya	Kotagala	80.60	6.92	252.66	238.83	263.52	224.24	402.85	550.04	464.47	529.34	416.01	441.27	382.55	106.54
N_Eliya	Ginigathena	80.48	7.00	444.81	425.59	485.37	552.86	212.07	197.50	237.67	274.70	255.58	351.85	217.38	211.08
N_Eliya	Katukithula	80.68	7.08	273.27	281.64	270.59	270.35	310.38	327.16	280.46	331.86	362.35	397.67	376.58	203.02
N_Eliya	Norton	80.52	6.92	358.98	326.07	421.90	384.44	226.85	220.66	225.36	209.14	212.07	241.99	243.66	132.32
N_Eliya	Maussakele	80.55	6.80	247.03	262.99	245.40	270.28	332.18	353.46	377.84	348.90	324.94	327.27	377.75	114.57

N_Eliya	Luxapana	80.52	6.90	352.83	350.12	421.88	429.48	351.45	357.18	347.05	280.78	265.82	258.69	275.81	127.66
N_Eliya	Castlerigh	80.57	6.87	356.88	345.52	414.18	377.53	152.35	151.31	192.63	141.29	166.22	174.42	165.91	150.87
Ratnapura	Balangoda	80.70	6.65	103.81	176.83	194.95	186.65	305.28	369.75	463.15	366.72	294.64	357.95	336.16	176.71
Ratnapura	Aluppola	80.58	6.72	293.69	330.42	377.44	371.95	303.92	255.52	329.88	286.56	281.18	349.30	267.06	267.78
Ratnapura	Ratnapura	80.40	6.68	302.11	339.32	371.22	352.93	290.62	310.81	341.58	291.75	354.08	357.21	285.56	219.75
Ratnapura	Galture	80.28	6.70	284.71	346.40	447.88	424.82	444.73	403.07	344.77	338.53	477.55	484.86	347.53	298.63
Monragala	Welipitiya Coconut	81.26	7.17	293.45	178.25	86.40	178.80	80.33	40.97	43.37	66.59	95.53	199.67	368.13	326.83

Calculations for Mini Hydro Scheme-01

Flow Coefficient	0.55	
Catchment area	9	km^2
Gross Head	320	m
Net Head	320	
Total Efficiency	80%	

Month	Rainfall (mm)	Available flow (mm)	Discharge (m3/month)	Flow rate (m3/s)	Flow rate (m3/s) descending order
January	240.617	132.34	1191052.50	0.445	0.678
February	264.605	145.53	1309796.05	0.541	0.649
March	330.737	181.91	1637147.37	0.611	0.648
April	363.079	199.69	1797240.79	0.693	0.600
May	365.426	200.98	1808860.26	0.675	0.578
June	426.021	234.31	2108804.21	0.814	0.565
July	420.647	231.36	2082204.47	0.777	0.563
August	366.647	201.66	1814904.47	0.678	0.560
September	351.832	193.51	1741566.32	0.672	0.509
October	389.542	214.25	1928233.42	0.720	0.451
November	408.105	224.46	2020121.05	0.779	0.371
December	221.291	121.71	1095390.00	0.409	0.341
Average Flow				0.651	

Available Power = 1634.9 kW

Available Power is Average flow X Available Head X Water density X Acceleration due to gravity X Efficiency factor

Investment (Rs)	365,637,738		
Loan (Rs)	255,946,417	70.00%	of the project cost
Equity (Rs)	109,691,322	30.00%	of the project cost
Loan Pay back period (years)	8		
interest	16.00%		
Insurance	0.05%	of the total cost	
Tariff (Rs/kWh)	16.70		
Escalation for Salaries	2.50%		
Escalation for other cost	2.50%		
Plant Factor	55.00%		

Description	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Remaining Loan (Rs)		255,946,417	223,953,114	191,959,811	159,966,508	127,973,205	95,979,902	63,986,599	31,993,296												
Revenue from sales (Rs)		136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020
Expenses																					
Repairs /Spares/Maintenance		4,467,600	4,579,290	4,693,772	4,811,117	4,931,394	5,054,679	5,181,046	5,310,572	5,443,337	5,579,420	5,718,906	5,861,878	6,008,425	6,158,636	6,312,602	6,470,417	6,632,177	6,797,982	6,967,931	7,142,130
Insurance (Rs)		182,819	187,389	192,074	196,876	201,798	206,843	212,014	217,314	222,747	228,316	234,024	239,874	245,871	252,018	258,318	264,776	271,396	278,181	285,135	292,263
Salaries (Rs)		2,449,020	2,510,246	2,573,002	2,637,327	2,703,260	2,770,841	2,840,112	2,911,115	2,983,893	3,058,490	3,134,953	3,213,326	3,293,660	3,376,001	3,460,401	3,546,911	3,635,584	3,726,474	3,819,635	3,915,126
Administrative (Rs)		2,978,400	3,052,860	3,129,182	3,207,411	3,287,596	3,369,786	3,454,031	3,540,382	3,628,891	3,719,613	3,812,604	3,907,919	4,005,617	4,105,757	4,208,401	4,313,611	4,421,452	4,531,988	4,645,288	4,761,420
Communication (Rs)		120,000	123,000	126,075	129,227	132,458	135,769	139,163	142,642	146,208	149,864	153,610	157,450	161,387	165,421	169,557	173,796	178,141	182,594	187,159	191,838
Major Overhaul (Rs)												73,127,548									

		10,197,839	10,452,785	10,714,104	10,981,957	11,256,506	11,537,919	11,826,367	12,122,026	12,425,076	12,735,703	86,181,644	13,380,448	13,714,960	14,057,834	14,409,279	14,769,511	15,138,749	15,517,218	15,905,148	16,302,777
Depreciation(Rs)		6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541
Operating profit (Rs)		119,682,640	119,427,694	119,166,375	118,898,522	118,623,973	118,342,560	118,054,112	117,758,453	117,455,403	117,144,776	43,698,835	116,500,031	116,165,519	115,822,645	115,471,200	115,110,968	114,741,730	114,363,261	113,975,331	113,577,702
Financial cost																					
Loan Interest (Rs)		28,793,972	24,954,776	21,115,580	23,035,177	17,916,249	12,797,320	7,678,392	2,559,464												
Profit Before tax (Rs)		90,888,668	94,472,918	98,050,795	95,863,345	100,707,724	105,545,240	110,375,721	115,198,990	117,455,403	117,144,776	43,698,835	116,500,031	116,165,519	115,822,645	115,471,200	115,110,968	114,741,730	114,363,261	113,975,331	113,577,702
Tax (Rs)		0	0	0	0	0	8,615,242	9,098,290	19,161,235	23,556,922	23,494,797	8,805,608	23,365,848	23,298,945	23,230,370	23,160,081	24,402,702	24,328,854	24,253,160	24,175,574	24,096,049
Profit after tax (Rs)		90,888,668	94,472,918	98,050,795	95,863,345	100,707,724	96,929,998	101,277,430	96,037,755	93,898,481	93,649,979	34,893,227	93,134,183	92,866,574	92,592,275	92,311,118	90,708,266	90,412,876	90,110,101	89,799,756	89,481,653
Cash Flow	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Net profit (Rs)		90,888,668	94,472,918	98,050,795	95,863,345	100,707,724	96,929,998	101,277,430	96,037,755	93,898,481	93,649,979	34,893,227	93,134,183	92,866,574	92,592,275	92,311,118	90,708,266	90,412,876	90,110,101	89,799,756	89,481,653
Add																					
Depreciation (Rs)		6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541
Less																					

Charges in Working Capital (Rs)		(10,823,351)	10,477	10,739	11,008	11,283	11,565	11,854	12,150	12,454	12,765	3,018,326	(2,991,830)	13,747	14,091	14,443	14,804	15,174	15,554	15,942	10,588,804
Capital Repayment (Rs)		31,993,303	31,993,303	31,993,303	31,993,303	31,993,303	31,993,303	31,993,303	31,993,303												
Net Cash flow (Rs)		76,621,257	69,371,679	72,949,293	70,761,575	75,605,680	71,827,671	76,174,814	70,934,843	100,788,568	100,539,755	38,777,442	103,028,554	99,755,368	99,480,725	99,199,216	97,596,003	97,300,243	96,997,088	96,686,355	85,795,391
Cumulative cash flow		76,621,257	145,992,936	218,942,229	289,703,804	365,309,484	437,137,155	513,311,970	584,246,812	685,035,380	785,575,134	824,352,576	927,381,130	1,027,136,498	1,126,617,223	1,225,816,440	1,323,412,443	1,420,712,685	1,517,709,773	1,614,396,128	1,700,191,519
Project IRR	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Capital Expenditure (Rs)	365,637,738.38																				
Net cash flow (Rs)		137,408,531.86	126,319,757.93	126,058,176.38	125,790,055.28	125,515,231.17	116,618,294.12	115,846,508.98	105,487,609.33	100,788,567.52	100,539,754.64	38,777,441.61	103,028,554.09	99,755,368.14	99,480,725.28	99,199,216.34	97,596,002.88	97,300,242.55	96,997,088.21	96,686,355.02	85,795,390.63
Perpetual value	(365,637,738.38)	137,408,531.86	126,319,757.93	126,058,176.38	125,790,055.28	125,515,231.17	116,618,294.12	115,846,508.98	105,487,609.33	100,788,567.52	100,539,754.64	38,777,441.61	103,028,554.09	99,755,368.14	99,480,725.28	99,199,216.34	97,596,002.88	97,300,242.55	96,997,088.21	96,686,355.02	85,795,390.63
		-228,229,207	-101,909,449	24,148,728	149,938,783																
				2,012,39	115,307,																

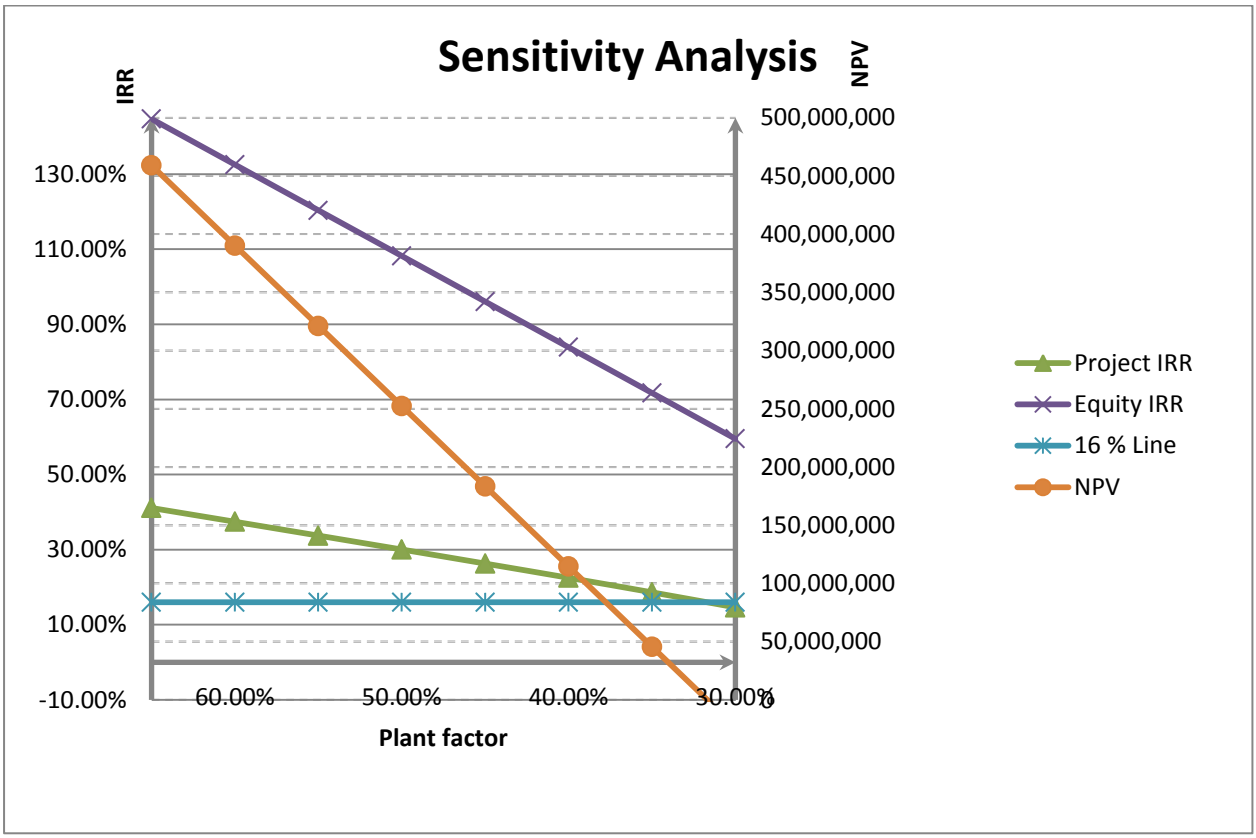
				4	551																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	-365,637,738	118,455,631	93,876,158	80,760,138	69,472,728	59,759,435	47,865,076	40,989,916	32,176,406	26,502,654	22,790,714	7,577,767	17,356,483	14,487,132	12,454,523	10,706,275	9,080,384	7,804,195	6,706,793	5,763,196	4,408,635
	-365,637,738	-247,182,107	-153,305,950	-72,545,812	-3,073,084	56,686,351	104,551,427	145,541,343	177,717,749	204,220,403	227,011,117	234,588,884	251,945,368	266,432,500	278,887,022	289,593,298	298,673,681	306,477,876	313,184,669	318,947,865	323,356,500
Project IRR	**33.79 %**																				
Equity IRR	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Capital Expenditure (Rs)	109,691,321.51																				
Net cash flow (Rs)		137,408,531.86	126,319,757.93	126,058,176.38	125,790,055.28	125,515,231.17	116,618,294.12	115,846,508.98	105,487,609.33	100,788,567.52	100,539,754.64	38,777,441.61	103,028,554.09	99,755,368.14	99,480,725.28	99,199,216.34	97,596,002.88	97,300,242.55	96,997,088.21	96,686,355.02	85,795,390.63
Perpetual value	(109,691,321.51)	137,408,531.86	126,319,757.93	126,058,176.38	125,790,055.28	125,515,231.17	116,618,294.12	115,846,508.98	105,487,609.33	100,788,567.52	100,539,754.64	38,777,441.61	103,028,554.09	99,755,368.14	99,480,725.28	99,199,216.34	97,596,002.88	97,300,242.55	96,997,088.21	96,686,355.02	85,795,390.63
Equity IRR	**120.38%**																				
NPV (Rs)	**323,356,500**																				
Pay Back	**74 mont**																				

	hs																				
Description	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Profit Before tax		90,888,668	94,472,918	98,050,795	95,863,345	100,707,724	105,545,240	110,375,721	115,198,990	117,455,403	117,144,776	43,698,835	116,500,031	116,165,519	115,822,645	115,471,200	115,110,968	114,741,730	114,363,261	113,975,331	113,577,702
Depreciation		6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541
Capital Allowance		26,295,358	26,295,358	26,295,358	26,295,358	26,295,358	26,295,358	26,295,358	26,295,358	6,573,334	6,573,334	6,573,334	6,573,334	6,573,334	6,573,334	6,573,334					
Taxable profit		71,495,851	75,080,101	78,657,978	76,470,528	81,314,907	86,152,423	90,982,904	95,806,173	117,784,610	117,473,983	44,028,042	116,829,238	116,494,726	116,151,852	115,800,407	122,013,509	121,644,271	121,265,802	120,877,872	120,480,243
Tax Rate		0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	10.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%
Taxation		0	0	0	0	0	8,615,242	9,098,290	19,161,235	23,556,922	23,494,797	8,805,608	23,365,848	23,298,945	23,230,370	23,160,081	24,402,702	24,328,854	24,253,160	24,175,574	24,096,049
Working Capital																					

Revenue	30	days																			
Cost	15	days																			
Total days in a year	365	days																			
	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*	*Year 9*	*Year 10*	*Year 11*	*Year 12*	*Year 13*	*Year 14*	*Year 15*	*Year 16*	*Year 17*	*Year 18*	*Year 19*	*Year 20*
Expected Revenue		136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020
Debtors period	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Total Debtors		11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440
Total O&M Costs		10,197,839	10,452,785	10,714,104	10,981,957	11,256,506	11,537,919	11,826,367	12,122,026	12,425,076	12,735,703	86,181,644	13,380,448	13,714,960	14,057,834	14,409,279	14,769,511	15,138,749	15,517,218	15,905,148	16,302,777
Creditors period	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Total Creditors		419,089	429,567	440,306	451,313	462,596	474,161	486,015	498,165	510,620	523,385	3,541,711	549,881	563,628	577,719	592,162	606,966	622,140	637,694	653,636	669,977
		(10,477)	(10,739)	(11,008)	(11,283)	(11,565)	(11,854)	(12,150)	(12,454)	(12,765)	(3,018,326)	2,991,830	(13,747)	(14,091)	(14,443)	(14,804)	(15,174)	(15,554)	(15,942)	(16,341)	669,977
Total Worki		10,823,3	10,812,8	10,802,1	10,791,1	10,779,8	10,768,2	10,756,4	10,744,2	10,731,8	10,719,0	7,700,72	10,692,5	10,678,8	10,664,7	10,650,2	10,635,4	10,620,3	10,604,7	10,588,8	10,572,4

ng Capital		51	73	34	27	44	79	25	75	20	55	9	59	12	21	78	74	00	46	04	63
Total Working CAPITAL Requirement		(10,823,351)	10,477	10,739	11,008	11,283	11,565	11,854	12,150	12,454	12,765	3,018,326	(2,991,830)	13,747	14,091	14,443	14,804	15,174	15,554	15,942	16,341

Plant Factror	Project IRR	Equity IRR	NPV
65.00%	41.09%	144.65%	458,949,357
60.00%	37.42%	132.49%	390,048,142
55.00%	33.73%	120.33%	321,146,926
50.00%	30.03%	108.17%	252,245,711
45.00%	26.29%	96.02%	183,344,496
40.00%	22.50%	83.86%	114,443,281
35.00%	18.63%	71.69%	45,542,066
30.00%	14.62%	59.49%	-23,359,149



Calculations for Mini Hydro Scheme-02

Flow Coefficient	0.55	
Catchment area	21	km^2
Available Head	63	m
Total Efficiency	80%	

Month	Rainfall (mm)	Available flow (mm)	Discharge (m3/month)	Flow rate (m3/s)	Flow rate (m3/s) descending order		
January	293.692	161.53	3392138.75	1.266	1.657	100	8.33
February	330.423	181.73	3816386.54	1.578	1.628	200	16.67
March	377.438	207.59	4359414.24	1.628	1.578	300	25.00
April	371.946	204.57	4295978.08	1.657	1.506	400	33.33
May	303.923	167.16	3510311.54	1.311	1.423	500	41.67
June	255.515	140.53	2951202.70	1.139	1.311	600	50.00
July	329.877	181.43	3810078.46	1.423	1.266	700	58.33
August	286.562	157.61	3309785.76	1.236	1.253	800	66.67
September	281.177	154.65	3247593.46	1.253	1.236	900	75.00
October	349.3	192.12	4034415.00	1.506	1.190	1000	83.33
November	267.062	146.88	3084560.76	1.190	1.155	1100	91.67
December	267.783	147.28	3092897.50	1.155	1.139	1200	100.00
Average Flow				1.361			

Available Power = 672.9 kW

Available Power is Average flow X Available Head X Water density X Acceleration due to gravity X Efficiency factor

Investment (Rs)	188,517,746		
Loan (Rs)	131,962,422	70.00%	of the project cost
Equity (Rs)	56,555,324	30.00%	of the project cost
Loan Pay back period (years)	8		
interest	16.00%		
Insurance	0.05%	of the total cost	
Tariff (Rs/kWh)	16.70		
Escalation for Salaries	2.50%		
Escalation for other cost	2.50%		
Plant Factor	55.00%		

Description	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Remaining Loan (Rs)		131,962,422	115,467,119	98,971,816	82,476,513	65,981,210	49,485,907	32,990,604	16,495,301												
Revenue from sales (Rs)		56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420
Expenses																					
Repairs /Spares /Maintenance		1,839,600	1,885,590	1,932,730	1,981,048	2,030,574	2,081,339	2,133,372	2,186,706	2,241,374	2,297,408	2,354,844	2,413,715	2,474,057	2,535,909	2,599,307	2,664,289	2,730,897	2,799,169	2,869,148	2,940,877
Insurance (Rs)		94,259	96,615	99,031	101,506	104,044	106,645	109,311	112,044	114,845	117,716	120,659	123,676	126,768	129,937	133,185	136,515	139,928	143,426	147,012	150,687
Salaries (Rs)		2,449,020	2,510,246	2,573,002	2,637,327	2,703,260	2,770,841	2,840,112	2,911,115	2,983,893	3,058,490	3,134,953	3,213,326	3,293,660	3,376,001	3,460,401	3,546,911	3,635,584	3,726,474	3,819,635	3,915,126
Administrative (Rs)		1,226,400	1,257,060	1,288,487	1,320,699	1,353,716	1,387,559	1,422,248	1,457,804	1,494,249	1,531,606	1,569,896	1,609,143	1,649,372	1,690,606	1,732,871	1,776,193	1,820,598	1,866,113	1,912,765	1,960,585
Communication (Rs)		120,000	123,000	126,075	129,227	132,458	135,769	139,163	142,642	146,208	149,864	153,610	157,450	161,387	165,421	169,557	173,796	178,141	182,594	187,159	191,838
Major Overhaul (Rs)												37,703,549									
		5,729,279	5,872,511	6,019,324	6,169,807	6,324,052	6,482,153	6,644,207	6,810,312	6,980,570	7,155,084	45,037,511	7,517,310	7,705,243	7,897,874	8,095,321	8,297,704	8,505,147	8,717,775	8,935,720	9,159,113
Deprec		4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24	4,24

iation(Rs)		6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667	6,667
Operating profit (Rs)		46,346,474	46,203,242	46,056,429	45,905,946	45,751,701	45,593,600	45,431,546	45,265,441	45,095,183	44,920,669	7,038,242	44,558,443	44,370,510	44,177,879	43,980,432	43,778,049	43,570,606	43,357,978	43,140,033	42,916,640	
Financial cost																						
Loan Interest (Rs)		14,845,773	12,866,337	10,886,900	11,876,618	9,237,369	6,598,121	3,958,872	1,319,624													
Profit Before tax (Rs)		31,500,701	33,336,905	35,169,529	34,029,328	36,514,332	38,995,479	41,472,674	43,945,817	45,095,183	44,920,669	7,038,242	44,558,443	44,370,510	44,177,879	43,980,432	43,778,049	43,570,606	43,357,978	43,140,033	42,916,640	
Tax (Rs)		0	0	0	0	0	2,706,048	2,953,767	6,402,163	9,047,037	9,012,134	1,435,648	8,939,689	8,902,102	8,863,576	8,824,086	9,604,943	9,563,455	9,520,929	9,477,340	9,432,661	
Profit after tax (Rs)		31,500,701	33,336,905	35,169,529	34,029,328	36,514,332	36,289,431	38,518,906	37,543,653	36,048,146	35,908,535	5,602,594	35,618,754	35,468,408	35,314,303	35,156,346	34,173,106	34,007,152	33,837,049	33,662,693	33,483,979	
Cash Flow	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	
Net profit (Rs)		31,500,701	33,336,905	35,169,529	34,029,328	36,514,332	36,289,431	38,518,906	37,543,653	36,048,146	35,908,535	5,602,594	35,618,754	35,468,408	35,314,303	35,156,346	34,173,106	34,007,152	33,837,049	33,662,693	33,483,979	
Add																						
Depreciation (Rs)		4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	
Less																						
Charges in Working Capital		(4,393,790)	5,886	6,033	6,184	6,339	6,497	6,660	6,826	6,997	7,172	1,556,812	(1,541,926)	7,723	7,916	8,114	8,317	8,525	8,738	8,957	4,262,019	

(Rs)																					
Capital Repayment (Rs)		16,495,303	16,495,303	16,495,303	16,495,303	16,495,303	16,495,303	16,495,303	16,495,303												
Net Cash flow (Rs)		23,645,855	21,082,383	22,914,860	21,774,508	24,259,357	24,034,298	26,263,610	25,288,191	40,287,817	40,148,030	8,292,449	41,407,347	39,707,352	39,553,054	39,394,898	38,411,456	38,245,294	38,074,978	37,900,404	33,468,627
Cumulative cash flow		23,645,855	44,728,238	67,643,098	89,417,606	113,676,963	137,711,261	163,974,871	189,263,063	229,550,879	269,698,909	277,991,358	319,398,705	359,106,057	398,659,111	438,054,009	476,465,465	514,710,758	552,785,736	590,686,139	624,154,767
Project IRR	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Capital Expenditure (Rs)	188,517,746.00																				
Net cash flow (Rs)		54,986,931.31	50,444,022.91	50,297,062.98	50,146,429.06	49,992,029.28	47,127,721.62	46,717,785.90	43,103,118.24	40,287,816.52	40,148,030.20	8,292,448.93	41,407,347.14	39,707,351.63	39,553,053.69	39,394,898.30	38,411,455.62	38,245,293.61	38,074,977.55	37,900,403.59	33,468,627.17
Perpetual value	(188,517,746.00)	54,986,931.31	50,444,022.91	50,297,062.98	50,146,429.06	49,992,029.28	47,127,721.62	46,717,785.90	43,103,118.24	40,287,816.52	40,148,030.20	8,292,448.93	41,407,347.14	39,707,351.63	39,553,053.69	39,394,898.30	38,411,455.62	38,245,293.61	38,074,977.55	37,900,403.59	33,468,627.17
		-133,530,815	-83,086,792	-32,789,729	17,356,700																
				-2,732,477	45,967,560																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	-188,5	47,402,5	37,488,1	32,223,1	27,695,4	23,801,8	19,343,2	16,530,1	13,147,5	10,593,8	9,100,90	1,620,48	6,975,59	5,766,56	4,951,85	4,251,77	3,573,82	3,067,55	2,632,66	2,259,13	1,719,80

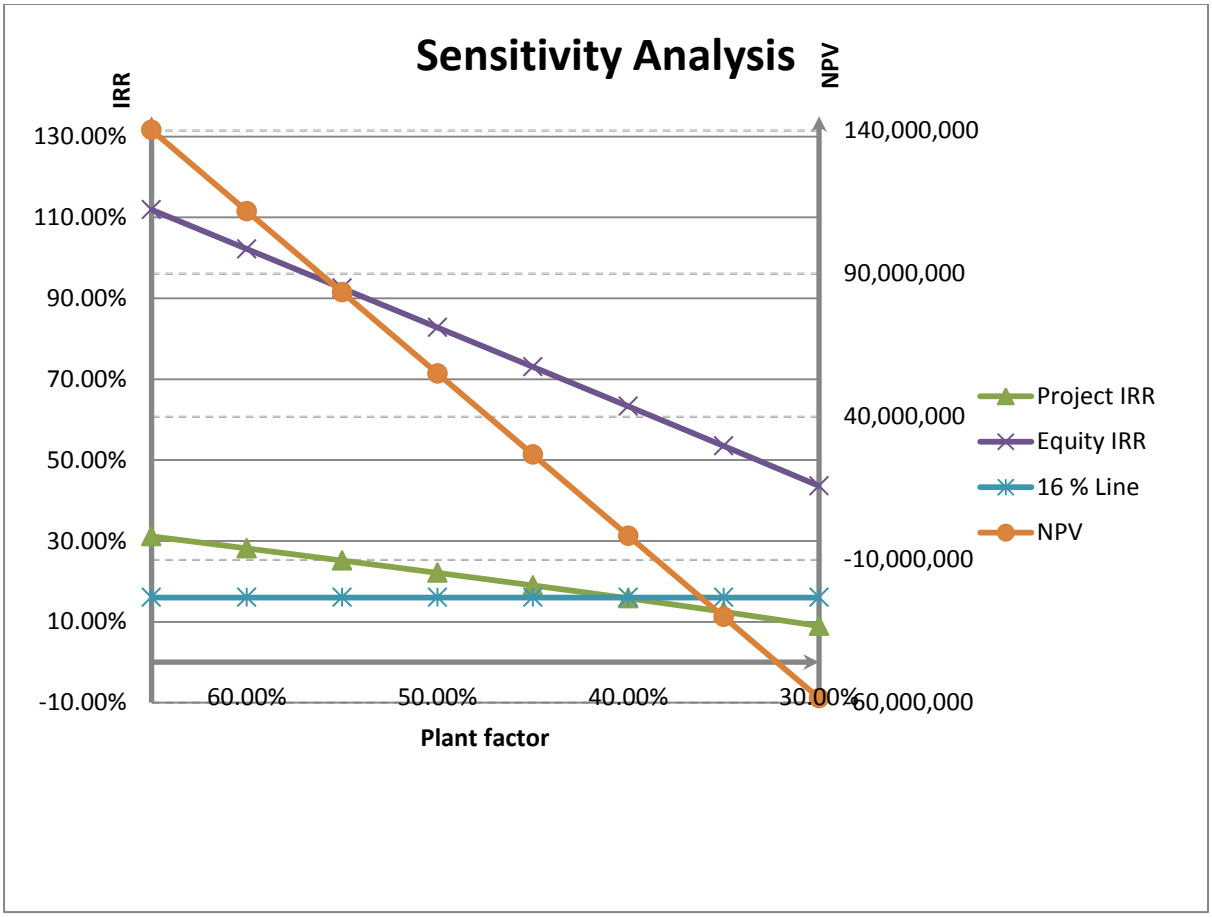
	17,746	27	26	99	26	56	08	32	48	01	0	5	9	3	8	4	2	4	7	4	1
	-188,517,746	-141,115,219	-103,627,093	-71,403,893	-43,708,467	-19,906,611	-563,403	15,966,729	29,114,278	39,708,079	48,808,979	50,429,464	57,405,064	63,171,627	68,123,485	72,375,258	75,949,081	79,016,634	81,649,301	83,908,435	85,628,236
Project IRR	**25.30 %**																				
Equity IRR	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Capital Expenditure (Rs)	56,555,323.80																				
Net cash flow (Rs)		54,986,931.31	50,444,022.91	50,297,062.98	50,146,429.06	49,992,029.28	47,127,721.62	46,717,785.90	43,103,118.24	40,287,816.52	40,148,030.20	8,292,448.93	41,407,347.14	39,707,351.63	39,553,053.69	39,394,898.30	38,411,455.62	38,245,293.61	38,074,977.55	37,900,403.59	33,468,627.17
Perpetual value	(56,555,323.80)	54,986,931.31	50,444,022.91	50,297,062.98	50,146,429.06	49,992,029.28	47,127,721.62	46,717,785.90	43,103,118.24	40,287,816.52	40,148,030.20	8,292,448.93	41,407,347.14	39,707,351.63	39,553,053.69	39,394,898.30	38,411,455.62	38,245,293.61	38,074,977.55	37,900,403.59	33,468,627.17
Equity IRR	**92.59 %**																				
NPV (Rs)	**85,628,236**																				
Pay Back	**74 months**																				
Description	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20

Profit Before tax		31,500,701	33,336,905	35,169,529	34,029,328	36,514,332	38,995,479	41,472,674	43,945,817	45,095,183	44,920,669	7,038,242	44,558,443	44,370,510	44,177,879	43,980,432	43,778,049	43,570,606	43,357,978	43,140,033	42,916,640
Depreciation		4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667	4,246,667
Capital Allowance		16,181,667	16,181,667	16,181,667	16,181,667	16,181,667	16,181,667	16,181,667	16,181,667	4,106,667	4,106,667	4,106,667	4,106,667	4,106,667	4,106,667	4,106,667					
Taxable profit		19,565,701	21,401,905	23,234,529	22,094,328	24,579,332	27,060,479	29,537,674	32,010,817	45,235,183	45,060,669	7,178,242	44,698,443	44,510,510	44,317,879	44,120,432	48,024,716	47,817,273	47,604,645	47,386,700	47,163,307
Tax Rate		0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	10.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%
Taxation		0	0	0	0	0	2,706,048	2,953,767	6,402,163	9,047,037	9,012,134	1,435,648	8,939,689	8,902,102	8,863,576	8,824,086	9,604,943	9,563,455	9,520,929	9,477,340	9,432,661
Working Capital																						
Revenue	30	days																				
Cost	15	days																				
Total days in a year	365	days																				

	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*	*Year 9*	*Year 10*	*Year 11*	*Year 12*	*Year 13*	*Year 14*	*Year 15*	*Year 16*	*Year 17*	*Year 18*	*Year 19*	*Year 20*
Expected Revenue		56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420	56,322,420
Debtors period	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Total Debtors		4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240	4,629,240
Total O&M Costs		5,729,279	5,872,511	6,019,324	6,169,807	6,324,052	6,482,153	6,644,207	6,810,312	6,980,570	7,155,084	45,037,511	7,517,310	7,705,243	7,897,874	8,095,321	8,297,704	8,505,147	8,717,775	8,935,720	9,159,113
Creditors period	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Total Creditors		235,450	241,336	247,369	253,554	259,893	266,390	273,050	279,876	286,873	294,045	1,850,857	308,931	316,654	324,570	332,684	341,002	349,527	358,265	367,221	376,402
		(5,886)	(6,033)	(6,184)	(6,339)	(6,497)	(6,660)	(6,826)	(6,997)	(7,172)	(1,556,812)	1,541,926	(7,723)	(7,916)	(8,114)	(8,317)	(8,525)	(8,738)	(8,957)	(9,181)	376,402
Total Working Capital		4,393,790	4,387,904	4,381,871	4,375,686	4,369,347	4,362,850	4,356,190	4,349,364	4,342,367	4,335,195	2,778,383	4,320,309	4,312,586	4,304,670	4,296,556	4,288,238	4,279,713	4,270,975	4,262,019	4,252,838
Total Working CAPITAL		(4,393,790)	5,886	6,033	6,184	6,339	6,497	6,660	6,826	6,997	7,172	1,556,812	(1,541,926)	7,723	7,916	8,114	8,317	8,525	8,738	8,957	9,181

Requirement																				

Plant Factror	Project IRR	Equity IRR	NPV
65.00%	31.13%	111.89%	140,160,839
60.00%	28.15%	102.17%	111,789,750
55.00%	25.14%	92.46%	83,418,662
50.00%	22.10%	82.75%	55,047,573
45.00%	18.99%	73.02%	26,676,485
40.00%	15.81%	63.27%	-1,694,604
35.00%	12.49%	53.48%	-30,065,693
30.00%	8.96%	43.59%	-58,436,781



Calculations for Mini Hydro Scheme-03

Flow Coefficient	0.55	
Catchment area	67	km^2
Available Head	65	m
Total Efficiency	80%	

Month	Rainfall (mm)	Available flow (mm)	Discharge (m3/month)	Flow rate (m3/s)	Flow rate (m3/s) descending order
January	195.808	107.69	7215513.45	2.694	7.458
February	199.108	109.51	7337142.07	3.033	7.034
March	242.145	133.18	8923060.02	3.331	6.816
April	383.415	210.88	14128856.94	5.451	6.269
May	511.231	281.18	18838853.84	7.034	5.937
June	440.938	242.52	16248582.32	6.269	5.451
July	431.546	237.35	15902475.77	5.937	5.430
August	376.408	207.02	13870647.07	5.179	5.179
September	479.431	263.69	17667023.84	6.816	4.006
October	542.108	298.16	19976692.07	7.458	3.331
November	381.975	210.09	14075778.75	5.430	3.033
December	291.167	160.14	10729491.68	4.006	2.694
Average Flow				5.229	

Available Power = 2662.4 kW

Available Power is Average flow X Available Head X Water density X Acceleration due to gravity X Efficiency factor

Investment (Rs)	580,718,759		
Loan (Rs)	406,503,132	70.00%	of the project cost
Equity (Rs)	174,215,628	30.00%	of the project cost
Loan Pay back period (years)	8		
interest	16.00%		
Insurance	0.05%	of the total cost	
Tariff (Rs/kWh)	16.70		
Escalation for Salaries	2.50%		
Escalation for other cost	2.50%		
Plant Factor	55.00%		

Description	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Remaining Loan (Rs)		406,503,132	355,690,240	304,877,348	254,064,456	203,251,564	152,438,672	101,625,780	50,812,888												
Revenue from sales (Rs)		217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620
Expenses																					
Repairs /Spares/Maintenance		7,095,600	7,272,990	7,454,815	7,641,185	7,832,215	8,028,020	8,228,721	8,434,439	8,645,300	8,861,432	9,082,968	9,310,042	9,542,793	9,781,363	10,025,897	10,276,544	10,533,458	10,796,795	11,066,714	11,343,382
Insurance (Rs)		290,359	297,618	305,059	312,685	320,502	328,515	336,728	345,146	353,775	362,619	371,685	380,977	390,501	400,264	410,270	420,527	431,040	441,816	452,862	464,183
Salaries (Rs)		2,449,020	2,510,246	2,573,002	2,637,327	2,703,260	2,770,841	2,840,112	2,911,115	2,983,893	3,058,490	3,134,953	3,213,326	3,293,660	3,376,001	3,460,401	3,546,911	3,635,584	3,726,474	3,819,635	3,915,126
Administrative (Rs)		4,730,400	4,848,660	4,969,877	5,094,123	5,221,476	5,352,013	5,485,814	5,622,959	5,763,533	5,907,621	6,055,312	6,206,695	6,361,862	6,520,909	6,683,931	6,851,030	7,022,305	7,197,863	7,377,810	7,562,255
Communication (Rs)		120,000	123,000	126,075	129,227	132,458	135,769	139,163	142,642	146,208	149,864	153,610	157,450	161,387	165,421	169,557	173,796	178,141	182,594	187,159	191,838
Major Overhaul (Rs)												116,143,752									

		14,685,379	15,052,514	15,428,827	15,814,547	16,209,911	16,615,159	17,030,538	17,456,301	17,892,709	18,340,027	134,942,279	19,268,490	19,750,203	20,243,958	20,750,057	21,268,808	21,800,528	22,345,541	22,904,180	23,476,784
Depreciation (Rs)		10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572
Operating profit (Rs)		192,319,669	191,952,534	191,576,221	191,190,501	190,795,137	190,389,889	189,974,510	189,548,747	189,112,339	188,665,021	72,062,769	187,736,558	187,254,845	186,761,090	186,254,991	185,736,240	185,204,520	184,659,507	184,100,868	183,528,264
Financial cost																					
Loan Interest (Rs)		45,731,603	39,634,056	33,536,509	36,585,282	28,455,219	20,325,156	12,195,093	4,065,031												
Profit Before tax (Rs)		146,588,066	152,318,478	158,039,712	154,605,219	162,339,918	170,064,733	177,779,417	185,483,716	189,112,339	188,665,021	72,062,769	187,736,558	187,254,845	186,761,090	186,254,991	185,736,240	185,204,520	184,659,507	184,100,868	183,528,264
Tax (Rs)		0	0	0	0	0	14,125,616	14,897,085	31,335,029	37,782,182	37,692,719	14,372,268	37,507,026	37,410,683	37,311,932	37,210,713	39,194,962	39,088,618	38,979,616	38,867,888	38,753,367
Profit after tax (Rs)		146,588,066	152,318,478	158,039,712	154,605,219	162,339,918	155,939,117	162,882,332	154,148,687	151,330,157	150,972,303	57,690,501	150,229,532	149,844,162	149,449,158	149,044,279	146,541,278	146,115,901	145,679,891	145,232,980	144,774,896
Cash Flow	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Net profit (Rs)		146,588,066	152,318,478	158,039,712	154,605,219	162,339,918	155,939,117	162,882,332	154,148,687	151,330,157	150,972,303	57,690,501	150,229,532	149,844,162	149,449,158	149,044,279	146,541,278	146,115,901	145,679,891	145,232,980	144,774,896
Add																					
Depreciation (Rs)		10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572
Less																					

Charges in Working Capital (Rs)		(17,252,131)	15,088	15,465	15,852	16,248	16,654	17,070	17,497	17,935	18,383	4,791,873	(4,753,717)	19,796	20,291	20,799	21,319	21,852	22,398	22,958	16,914,372
Capital Repayment (Rs)		50,812,892	50,812,892	50,812,892	50,812,892	50,812,892	50,812,892	50,812,892	50,812,892												
Net Cash flow (Rs)		123,265,877	111,729,070	117,449,927	114,015,048	121,749,350	115,348,143	122,290,942	113,556,870	161,550,794	161,192,492	63,137,199	165,221,821	160,062,938	159,667,439	159,262,052	156,758,531	156,332,622	155,896,065	155,448,594	138,099,096
Cumulative cash flow		123,265,877	234,994,947	352,444,875	466,459,922	588,209,273	703,557,415	825,848,357	939,405,227	1,100,956,021	1,262,148,513	1,325,285,713	1,490,507,534	1,650,570,471	1,810,237,910	1,969,499,962	2,126,258,493	2,282,591,115	2,438,487,180	2,593,935,774	2,732,034,870
Project IRR	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Capital Expenditure (Rs)	580,718,759.43																				
Net cash flow (Rs)		219,810,371.88	202,176,018.42	201,799,328.38	201,413,221.09	201,017,461.11	186,486,190.94	185,298,927.24	168,434,792.67	161,550,794.41	161,192,491.87	63,137,199.36	165,221,821.07	160,062,937.52	159,667,438.56	159,262,052.12	156,758,531.02	156,332,621.90	155,896,065.05	155,448,594.27	138,099,096.09
Perpetual value	(580,718,759.43)	219,810,371.88	202,176,018.42	201,799,328.38	201,413,221.09	201,017,461.11	186,486,190.94	185,298,927.24	168,434,792.67	161,550,794.41	161,192,491.87	63,137,199.36	165,221,821.07	160,062,937.52	159,667,438.56	159,262,052.12	156,758,531.02	156,332,621.90	155,896,065.05	155,448,594.27	138,099,096.09
		-360,908,388	-158,732,369	43,066,959	244,480,180																

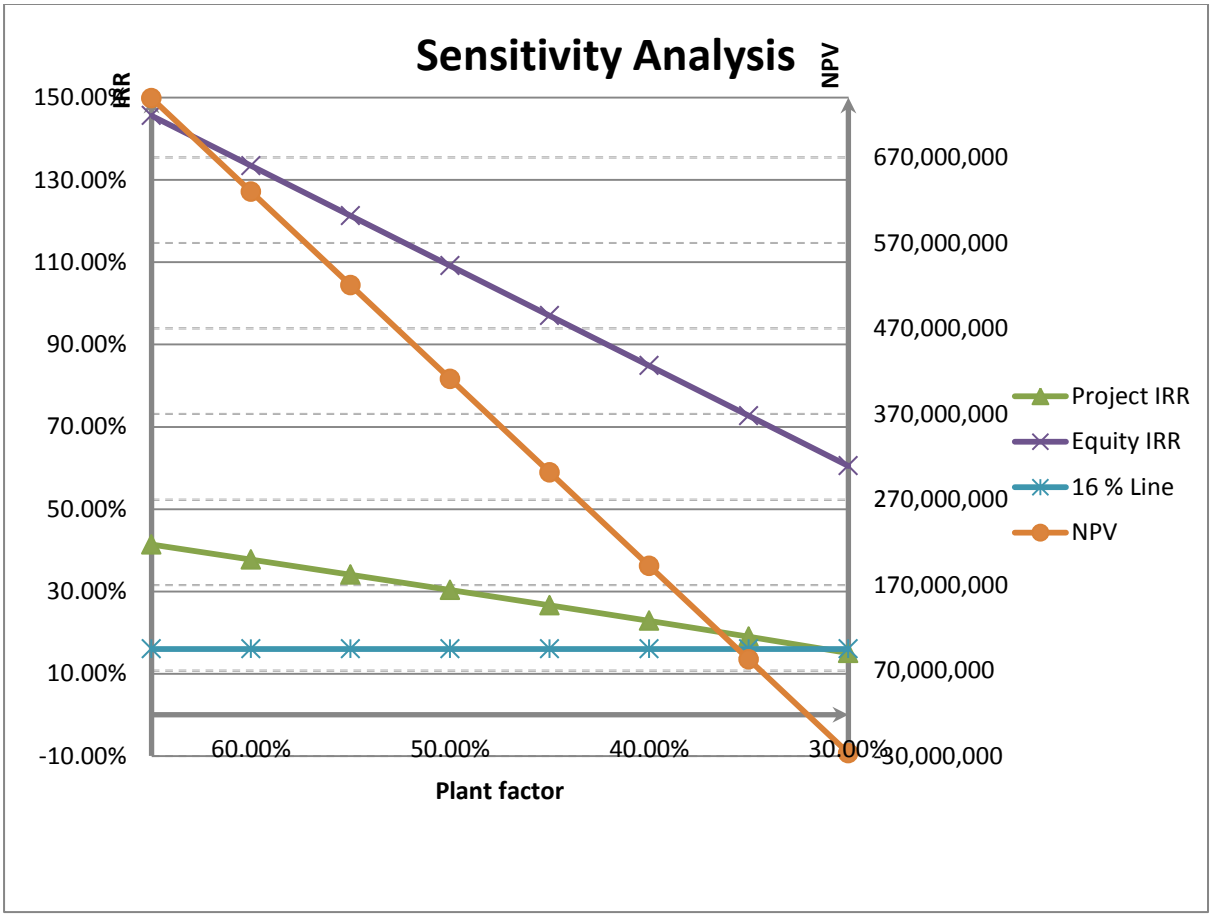
				3,588,913	184,628,786																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	-580,718,759	189,491,700	150,249,716	129,284,288	111,238,729	95,707,030	76,541,813	65,564,232	51,376,900	42,480,263	36,539,695	12,338,076	27,833,738	23,245,395	19,989,619	17,188,678	14,584,897	12,539,026	10,779,320	9,265,844	7,096,285
	-580,718,759	-391,227,060	-240,977,343	-111,693,055	-454,326	95,252,704	171,794,516	237,358,749	288,735,648	331,215,911	367,755,606	380,093,682	407,927,420	431,172,814	451,162,433	468,351,111	482,936,007	495,475,033	506,254,353	515,520,197	522,616,482
Project IRR	**34.08%**																				
Equity IRR	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Capital Expenditure (Rs)	174,215,627.83																				
Net cash flow (Rs)		219,810,371.88	202,176,018.42	201,799,328.38	201,413,221.09	201,017,461.11	186,486,190.94	185,298,927.24	168,434,792.67	161,550,794.41	161,192,491.87	63,137,199.36	165,221,821.07	160,062,937.52	159,667,438.56	159,262,052.12	156,758,531.02	156,332,621.90	155,896,065.05	155,448,594.27	138,099,096.09
Perpetual value	(174,215,627.83)	219,810,371.88	202,176,018.42	201,799,328.38	201,413,221.09	201,017,461.11	186,486,190.94	185,298,927.24	168,434,792.67	161,550,794.41	161,192,491.87	63,137,199.36	165,221,821.07	160,062,937.52	159,667,438.56	159,262,052.12	156,758,531.02	156,332,621.90	155,896,065.05	155,448,594.27	138,099,096.09
Equity IRR	**121.31%**																				
NPV (Rs)	**522,616,482**																				

Pay Back	**74 months**																				
Description	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Profit Before tax		146,588,066	152,318,478	158,039,712	154,605,219	162,339,918	170,064,733	177,779,417	185,483,716	189,112,339	188,665,021	72,062,769	187,736,558	187,254,845	186,761,090	186,254,991	185,736,240	185,204,520	184,659,507	184,100,868	183,528,264
Depreciation		10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572	10,238,572
Capital Allowance		39,047,143	39,047,143	39,047,143	39,047,143	39,047,143	39,047,143	39,047,143	39,047,143	10,440,000	10,440,000	10,440,000	10,440,000	10,440,000	10,440,000	10,440,000					
Taxable profit		117,779,495	123,509,907	129,231,141	125,796,648	133,531,347	141,256,162	148,970,846	156,675,145	188,910,911	188,463,593	71,861,341	187,535,130	187,053,417	186,559,662	186,053,563	195,974,812	195,443,092	194,898,079	194,339,440	193,766,836
Tax Rate		0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	10.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%
Taxation		0	0	0	0	0	14,125,616	14,897,085	31,335,029	37,782,182	37,692,719	14,372,268	37,507,026	37,410,683	37,311,932	37,210,713	39,194,962	39,088,618	38,979,616	38,867,888	38,753,367
Working																					

Capital																					
Revenue	30	days																			
Cost	15	days																			
Total days in a year	365	days																			
	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*	*Year 9*	*Year 10*	*Year 11*	*Year 12*	*Year 13*	*Year 14*	*Year 15*	*Year 16*	*Year 17*	*Year 18*	*Year 19*	*Year 20*
Expected Revenue		217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620	217,243,620
Debtors period	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Total Debtors		17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640	17,855,640
Total O&M Costs		14,685,379	15,052,514	15,428,827	15,814,547	16,209,911	16,615,159	17,030,538	17,456,301	17,892,709	18,340,027	134,942,279	19,268,490	19,750,203	20,243,958	20,750,057	21,268,808	21,800,528	22,345,541	22,904,180	23,476,784
Creditors period	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Total Creditors		603,509	618,596	634,061	649,913	666,161	682,815	699,885	717,382	735,317	753,700	5,545,573	791,856	811,652	831,943	852,742	874,061	895,912	918,310	941,268	964,799
		(15,088)	(15,465)	(15,852)	(16,248)	(16,654)	(17,070)	(17,497)	(17,935)	(18,383)	(4,791,873)	4,753,717	(19,796)	(20,291)	(20,799)	(21,319)	(21,852)	(22,398)	(22,958)	(23,532)	964,799

Total Working Capital		17,252,131	17,237,044	17,221,579	17,205,727	17,189,479	17,172,825	17,155,755	17,138,258	17,120,323	17,101,940	12,310,067	17,063,784	17,043,988	17,023,697	17,002,898	16,981,579	16,959,728	16,937,330	16,914,372	16,890,841
Total Working CAPITAL Requirement		(17,252,131)	15,088	15,465	15,852	16,248	16,654	17,070	17,497	17,935	18,383	4,791,873	(4,753,717)	19,796	20,291	20,799	21,319	21,852	22,398	22,958	23,532

Plant Factror	Project IRR	Equity IRR	NPV
65.00%	41.39%	145.59%	739,269,591
60.00%	37.73%	133.43%	629,838,250
55.00%	34.05%	121.27%	520,406,908
50.00%	30.35%	109.12%	410,975,566
45.00%	26.62%	96.97%	301,544,225
40.00%	22.84%	84.82%	192,112,883
35.00%	18.99%	72.66%	82,681,541
30.00%	15.01%	60.47%	-26,749,800



Calculations for Mini Hydro Scheme-04

Flow Coefficient	0.55	
Catchment area	175	km^2
Available Head	29	m
Total Efficiency	80%	

Month	Rainfall (mm)	Available flow (mm)	Discharge (m3/month)	Flow rate (m3/s)	Flow rate (m3/s) descending order
January	162.323	89.28	15623596.16	5.833	16.395
February	168.192	92.51	16188509.65	6.692	15.316
March	243.808	134.09	23466490.36	8.761	12.395
April	441.508	242.83	42495115.36	16.395	8.761
May	119.131	65.52	11466336.52	4.281	8.356
June	60.3846	33.21	5812019.19	2.242	6.692
July	38.1667	20.99	3673541.70	1.372	5.833
August	59.4231	32.68	5719471.16	2.135	4.281
September	104.773	57.62	10084374.97	3.891	3.891
October	344.923	189.71	33198846.16	12.395	2.242
November	412.462	226.85	39699423.03	15.316	2.135
December	232.523	127.89	22380346.16	8.356	1.372
Average flow				7.287	

Available Power = 1658.4 kW

Available Power is Average flow X Available Head X Water density X Acceleration due to gravity X Efficiency factor

Investment (Rs)	365,637,738	
Loan (Rs)	255,946,417	70.00%
Equity (Rs)	109,691,322	30.00%
Loan Pay back period (years)	8	
interest	16.00%	
Insurance	0.05%	of the total cost
Tariff (Rs/kWh)	16.70	
Escalation for Salaries	2.50%	
Escalation for other cost	2.50%	
Plant Factor	55.00%	

Description	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Remaining Loan (Rs)		255,946,417	223,953,114	191,959,811	159,966,508	127,973,205	95,979,902	63,986,599	31,993,296												
Revenue from sales (Rs)		136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020
Expenses																					
Repairs /Spares/Maintenance		4,467,600	4,579,290	4,693,772	4,811,117	4,931,394	5,054,679	5,181,046	5,310,572	5,443,337	5,579,420	5,718,906	5,861,878	6,008,425	6,158,636	6,312,602	6,470,417	6,632,177	6,797,982	6,967,931	7,142,130
Insurance (Rs)		182,819	187,389	192,074	196,876	201,798	206,843	212,014	217,314	222,747	228,316	234,024	239,874	245,871	252,018	258,318	264,776	271,396	278,181	285,135	292,263
Salaries (Rs)		2,449,020	2,510,246	2,573,002	2,637,327	2,703,260	2,770,841	2,840,112	2,911,115	2,983,893	3,058,490	3,134,953	3,213,326	3,293,660	3,376,001	3,460,401	3,546,911	3,635,584	3,726,474	3,819,635	3,915,126
Administrative (Rs)		2,978,400	3,052,860	3,129,182	3,207,411	3,287,596	3,369,786	3,454,031	3,540,382	3,628,891	3,719,613	3,812,604	3,907,919	4,005,617	4,105,757	4,208,401	4,313,611	4,421,452	4,531,988	4,645,288	4,761,420
Communication (Rs)		120,000	123,000	126,075	129,227	132,458	135,769	139,163	142,642	146,208	149,864	153,610	157,450	161,387	165,421	169,557	173,796	178,141	182,594	187,159	191,838
Major Overhaul (Rs)												73,127,548									

		10,197,839	10,452,785	10,714,104	10,981,957	11,256,506	11,537,919	11,826,367	12,122,026	12,425,076	12,735,703	86,181,644	13,380,448	13,714,960	14,057,834	14,409,279	14,769,511	15,138,749	15,517,218	15,905,148	16,302,777
Depreciation(Rs)		6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541
Operating profit (Rs)		119,682,640	119,427,694	119,166,375	118,898,522	118,623,973	118,342,560	118,054,112	117,758,453	117,455,403	117,144,776	43,698,835	116,500,031	116,165,519	115,822,645	115,471,200	115,110,968	114,741,730	114,363,261	113,975,331	113,577,702
Financial cost																					
Loan Interest (Rs)		28,793,972	24,954,776	21,115,580	23,035,177	17,916,249	12,797,320	7,678,392	2,559,464												
Profit Before tax (Rs)		90,888,668	94,472,918	98,050,795	95,863,345	100,707,724	105,545,240	110,375,721	115,198,990	117,455,403	117,144,776	43,698,835	116,500,031	116,165,519	115,822,645	115,471,200	115,110,968	114,741,730	114,363,261	113,975,331	113,577,702
Tax (Rs)		0	0	0	0	0	8,615,242	9,098,290	19,161,235	23,556,922	23,494,797	8,805,608	23,365,848	23,298,945	23,230,370	23,160,081	24,402,702	24,328,854	24,253,160	24,175,574	24,096,049
Profit after tax (Rs)		90,888,668	94,472,918	98,050,795	95,863,345	100,707,724	96,929,998	101,277,430	96,037,755	93,898,481	93,649,979	34,893,227	93,134,183	92,866,574	92,592,275	92,311,118	90,708,266	90,412,876	90,110,101	89,799,756	89,481,653
Cash Flow	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Net profit (Rs)		90,888,668	94,472,918	98,050,795	95,863,345	100,707,724	96,929,998	101,277,430	96,037,755	93,898,481	93,649,979	34,893,227	93,134,183	92,866,574	92,592,275	92,311,118	90,708,266	90,412,876	90,110,101	89,799,756	89,481,653
Add																					
Depreciation (Rs)		6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541
Less																					

Charges in Working Capital (Rs)		(10,823,351)	10,477	10,739	11,008	11,283	11,565	11,854	12,150	12,454	12,765	3,018,326	(2,991,830)	13,747	14,091	14,443	14,804	15,174	15,554	15,942	10,588,804
Capital Repayment (Rs)		31,993,303	31,993,303	31,993,303	31,993,303	31,993,303	31,993,303	31,993,303	31,993,303												
Net Cash flow (Rs)		76,621,257	69,371,679	72,949,293	70,761,575	75,605,680	71,827,671	76,174,814	70,934,843	100,788,568	100,539,755	38,777,442	103,028,554	99,755,368	99,480,725	99,199,216	97,596,003	97,300,243	96,997,088	96,686,355	85,795,391
Cumulative cash flow		76,621,257	145,992,936	218,942,229	289,703,804	365,309,484	437,137,155	513,311,970	584,246,812	685,035,380	785,575,134	824,352,576	927,381,130	1,027,136,498	1,126,617,223	1,225,816,440	1,323,412,443	1,420,712,685	1,517,709,773	1,614,396,128	1,700,191,519
Project IRR	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Capital Expenditure (Rs)	365,637,738.38																				
Net cash flow (Rs)		137,408,531.86	126,319,757.93	126,058,176.38	125,790,055.28	125,515,231.17	116,618,294.12	115,846,508.98	105,487,609.33	100,788,567.52	100,539,754.64	38,777,441.61	103,028,554.09	99,755,368.14	99,480,725.28	99,199,216.34	97,596,002.88	97,300,242.55	96,997,088.21	96,686,355.02	85,795,390.63
Perpetual value	(365,637,738.38)	137,408,531.86	126,319,757.93	126,058,176.38	125,790,055.28	125,515,231.17	116,618,294.12	115,846,508.98	105,487,609.33	100,788,567.52	100,539,754.64	38,777,441.61	103,028,554.09	99,755,368.14	99,480,725.28	99,199,216.34	97,596,002.88	97,300,242.55	96,997,088.21	96,686,355.02	85,795,390.63
		-228,229,207	-101,909,449	24,148,728	149,938,783																
				2,012,39	115,307,																

				4	551																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	-365,637,738	118,455,631	93,876,158	80,760,138	69,472,728	59,759,435	47,865,076	40,989,916	32,176,406	26,502,654	22,790,714	7,577,767	17,356,483	14,487,132	12,454,523	10,706,275	9,080,384	7,804,195	6,706,793	5,763,196	4,408,635
	-365,637,738	-247,182,107	-153,305,950	-72,545,812	-3,073,084	56,686,351	104,551,427	145,541,343	177,717,749	204,220,403	227,011,117	234,588,884	251,945,368	266,432,500	278,887,022	289,593,298	298,673,681	306,477,876	313,184,669	318,947,865	323,356,500
Project IRR	**33.79 %**																				
Equity IRR	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Capital Expenditure (Rs)	109,691,321.51																				
Net cash flow (Rs)		137,408,531.86	126,319,757.93	126,058,176.38	125,790,055.28	125,515,231.17	116,618,294.12	115,846,508.98	105,487,609.33	100,788,567.52	100,539,754.64	38,777,441.61	103,028,554.09	99,755,368.14	99,480,725.28	99,199,216.34	97,596,002.88	97,300,242.55	96,997,088.21	96,686,355.02	85,795,390.63
Perpetual value	(109,691,321.51)	137,408,531.86	126,319,757.93	126,058,176.38	125,790,055.28	125,515,231.17	116,618,294.12	115,846,508.98	105,487,609.33	100,788,567.52	100,539,754.64	38,777,441.61	103,028,554.09	99,755,368.14	99,480,725.28	99,199,216.34	97,596,002.88	97,300,242.55	96,997,088.21	96,686,355.02	85,795,390.63
Equity IRR	**120.38%**																				
NPV (Rs)	**323,356,500**																				
Pay Back	**74 mont**																				

	hs																			
Description	Year 00	Year 01	Year 02	Year 03	Year 04	Year 05	Year 06	Year 07	Year 08	Year 09	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Profit Before tax		90,888,668	94,472,918	98,050,795	95,863,345	100,707,724	105,545,240	110,375,721	115,198,990	117,455,403	117,144,776	43,698,835	116,500,031	116,165,519	115,822,645	115,471,200	115,110,968	114,741,730	114,363,261	113,975,331	113,577,702
Depreciation		6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541	6,902,541
Capital Allowance		26,295,358	26,295,358	26,295,358	26,295,358	26,295,358	26,295,358	26,295,358	26,295,358	6,573,334	6,573,334	6,573,334	6,573,334	6,573,334	6,573,334	6,573,334					
Taxable profit		71,495,851	75,080,101	78,657,978	76,470,528	81,314,907	86,152,423	90,982,904	95,806,173	117,784,610	117,473,983	44,028,042	116,829,238	116,494,726	116,151,852	115,800,407	122,013,509	121,644,271	121,265,802	120,877,872	120,480,243
Tax Rate		0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	10.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%	20.00%
Taxation		0	0	0	0	0	8,615,242	9,098,290	19,161,235	23,556,922	23,494,797	8,805,608	23,365,848	23,298,945	23,230,370	23,160,081	24,402,702	24,328,854	24,253,160	24,175,574	24,096,049
Working Capital																					

Revenue	30	days																			
Cost	15	days																			
Total days in a year	365	days																			
	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	*Year 7*	*Year 8*	*Year 9*	*Year 10*	*Year 11*	*Year 12*	*Year 13*	*Year 14*	*Year 15*	*Year 16*	*Year 17*	*Year 18*	*Year 19*	*Year 20*
Expected Revenue		136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020	136,783,020
Debtors period	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Total Debtors		11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440	11,242,440
Total O&M Costs		10,197,839	10,452,785	10,714,104	10,981,957	11,256,506	11,537,919	11,826,367	12,122,026	12,425,076	12,735,703	86,181,644	13,380,448	13,714,960	14,057,834	14,409,279	14,769,511	15,138,749	15,517,218	15,905,148	16,302,777
Creditors period	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Total Creditors		419,089	429,567	440,306	451,313	462,596	474,161	486,015	498,165	510,620	523,385	3,541,711	549,881	563,628	577,719	592,162	606,966	622,140	637,694	653,636	669,977
		(10,477)	(10,739)	(11,008)	(11,283)	(11,565)	(11,854)	(12,150)	(12,454)	(12,765)	(3,018,326)	2,991,830	(13,747)	(14,091)	(14,443)	(14,804)	(15,174)	(15,554)	(15,942)	(16,341)	669,977
Total Worki		10,823,3	10,812,8	10,802,1	10,791,1	10,779,8	10,768,2	10,756,4	10,744,2	10,731,8	10,719,0	7,700,72	10,692,5	10,678,8	10,664,7	10,650,2	10,635,4	10,620,3	10,604,7	10,588,8	10,572,4

ng Capital		51	73	34	27	44	79	25	75	20	55	9	59	12	21	78	74	00	46	04	63
Total Working CAPITAL Requirement		(10,823,351)	10,477	10,739	11,008	11,283	11,565	11,854	12,150	12,454	12,765	3,018,326	(2,991,830)	13,747	14,091	14,443	14,804	15,174	15,554	15,942	16,341

Plant Factror	Project IRR	Equity IRR	NPV
65.00%	41.09%	144.65%	458,949,357
60.00%	37.42%	132.49%	390,048,142
55.00%	33.73%	120.33%	321,146,926
50.00%	30.03%	108.17%	252,245,711
45.00%	26.29%	96.02%	183,344,496
40.00%	22.50%	83.86%	114,443,281
35.00%	18.63%	71.69%	45,542,066
30.00%	14.62%	59.49%	-23,359,149