ovara

14 May 2002

Mr. Dhammika Perera
Chairman
Zyrex Power Company Erathna Limited
Level 27 East Tower
World Trade Center
Colombo1.

Dear Mr. Perera,

FEASIBILITY STUDY
ERATHNA SMALL HYDRO POWER PROJECT

I am attaching the Final Feasibility Report for your review. If you have any clarifications please let us know for us to arrange a meeting with our consultants. I would appreciate it if you would release the balance payment of for the services undertaken up to the date of the submission of the Final Feasibility Report.

My consultants and I are available for extending consultancy services for the implementation of this project. Our scope would include attending meeting with lenders and liaising with village community leaders to address their concerns as well. If you are interested in pursuing this proposal please arrange a meeting.

On a personal note I would request the quick payment as one our consultants is leaving next week for an overseas assignment.

Yours sincerely,

Keerthi Wickramasuriya
Chief Executive Officer

O V A R A
(PRIVATE) LIMITED
Tel 94 (0) 74 714328, 94 (0) 74 714339
E-mail: ovara@wow.lk
244 Vauxhall Street
Colombo 02
Sri Lanka

ERATHNA SMALL HYDRO POWER PROJECT

FEASIBILITY STUDY

ZYREX POWER COMPANY ERATHNA LIMITED
27-2, East Tower, World Trade Centre, Echelon Square, Colombo1. Sri Lanka.
Tel: 94-1-381115 E-mail: vallibel@lanka.ccom.lk

Erathna

CONSULTANTS
OVARA (PRIVATE)LIMITED
244, Vauxhall Street,
Colombo 2.

CONTENTS

1. Executive Summary

1.1 General

In keeping with government policy to open the Hydropower Electricity Generation sector to private and institutional investors, the Ceylon Electricity Board made a policy decision to purchase all power supplied by small hydro developers at a rate which was worked out in consultation with the World Bank and on the avoided cost principle. In order to kick-start the industry the Board of Investment of Sri Lanka announced a concessionary tax package. Development projects of this nature were classified under large infrastructure development projects. Such companies are exempted from income tax for a period of 10 years after commencement of commercial generation to feed the national grid. In addition duty free facilities were awarded for the importation of plant and equipment and a VAT refund scheme was also put in to place.

1.2 Objectives

With a view to participate in this development program a legal entity exclusively for the development of hydropower for grid connection under the style of Zyrex Power Company Erathna Limited was incorporated under the purview of the Board of Investment and with a view of developing Erathna Hydropower Project with a investment in excess of Rs. 650 million. The project is to develop a plant with a capacity of 9.9 MW on Built Own and Operate basis.

1.3 The Report

The report consists of the following subjects, which would be dealt in depth in the following chapters.

1.3.1 Introduction

Is dealt with in-depth in the Report under the appropriate heading.

1.3.2 Topography

The topographical maps available and the ground surveys carried out for the design of the project is described and a review of the topography of the river, river valley and project area is made. Access road, land requirements and ownership are dealt with.

1.3.3 Geology

A geological and geo-technical review of the project area and sites is made. All civil designs and other related work including road construction were based on these findings.

1.3.4 Hydrology

Catchment area of the proposed site is 14.5 km2 and the annual rainfall 4841 mm. The hydrology of the area is evaluated and a hydrology model established to generate daily stream flows for 29 years.

1.3.5 Environment

A detailed environmental study was done and Central Environmental Authority clearance was obtained. Floral and Faunal surveys were also completed. A further study has been carried out based on the Terms of Reference specified by the World Bank office in Colombo.

1.3.6 Project Alternatives

The possibility of the project being constructed on the left bank of Kuru Ganga is examined and the option rejected on account of environmental reasons. Alternatives of cascade development, location of weir and powerhouse and layout of water conveyance system is examined.

1.3.7 Plant Sizing and Optimization

Plant sizing and optimization were done on the basis of flow duration curves and also daily flows developed by the hydrology study. Penstock size was optimized. Energy generation and project cost was estimated and the NPV was determined for various plant capacities and the optimum plant capacity selected.

1.3.8 Project Features

Project Name	Erathna Mini Hydro Power Project
Plant Capacity	9.9 MW
Annual Energy Generation :	32.3 GWH
Plant factor	37.2 %
Location	Province: Sabaragamuwa District : Ratnapura DS Division : Kuruwita
River Catchment / Sub catchment	Kalu Ganga / Kuru Ganga
Catchment area	14.5 km2
Average annual rainfall	4841 mm.
Mean Flow	1.30 cumecs
Design Flood Flow	85 cumecs
Elevation at weir point	840 m. MSL
Elevation at tail water discharge point	377 m. MSL
Gross Head	462 m
Net Head	426 m
Promoters	Mr. Dammika Perera, Valibel Lanka (Private) Limited

1.3.9 Technical Details

Weir	
Type	Concrete Gravity
Length	20 m
Height	2 m
Intake Conduit	
Length	10 m
Section	2m x 1m
Headrace Channel	
Length	280 m
Section	2m x 1.2m
Sedimentation Tank	
Design particle size	0.2
Length	27 m
Section	6 m x 2.7m
Forebay tank	
Capacity	145 Cu m
Penstock	
Length	2400 m
Thickness range	8 to 16 mm
Diameter range	620 mm to 1118 mm
Head loss at full flow	36 m
Expansion Joints	Sleeve
Penstock supports and Anchors	
No. of Anchors	38
No. of Supports	200

Power house	
Size	18 m x 30 m
Type	Open Air
Hydraulic Turbine	
Type	Horizontal shaft Pelton
Rated Head	426 m
Number of units	2
Design Flow of one unit	1.35 M3/sec
Governer	Hydraulic with head level sensor
Generator	
No. of units	2
Type	Brushless, Synchronous
Duty	Continous
Shaft	Horizantal
Rated Output of one unit	4.95 MW
Generating Voltage	6.3 kV
Power Factor	.9 –1
Rated Speed	750 rpm
Runaway speed	1320 rpm
Generatror Efficiency	97.6 at rated output
Protection	
Over/Under Voltage	Yes
Over/Under Frequency	Yes
Over Current	Yes
Loss of Mains (ROCOF)	Yes
Earth Fault	Yes
Neutral Voltage Displacement	Yes

1.3.9 Financial Overview

Revenue	Net annual Production	32.3 GWH
	Net Annual Revenue for the First year	182.5 Million
Cost	E&M	460.4 Million
	Civil	159.3 Million
	Other	72.4 Million

1.3.10 Planning

Loan	2003 April
E&M	2003 May
Civil	2001 November
Commercial Operation	2004 May

2. Introduction

2.1 Promoters

Zyrex Power Company Erathna Limited together with Vallibel Lanka (Pvt) Ltd and Mr. K.D. Dhammika Perera.

Mr. K.D. Dhammika Perera's investments cover a wide spectrum including entertainment, investment in and ownership of cargo vessels and other miscellaneous businesses.

In addition to the above, the diversity of Mr. Dhammika Perera's investments cover some of the blue chip companies' quoted on the Stock Exchange. Mr. Perera is the largest shareholder of Pan Asia Bank Ltd. He is also one of the largest stakeholders in the National Development Bank and Royal Ceramic Ltd. Mr. Perera serves on the board of all three companies.

Special mention must be made of Mr.K.D. Dhammika Perera's present involvement and investment in the Hydropower sector. Parallel to the Etathna Project Didul (Pvt) Ltd is well on stream in the development of the Way Ganga Small Hydro Power Project (WGSHP) with an installed capacity of 9MW. This same company has obtained approval for the development of the Gin Ganga Hydropower Project (GGHHP) at Watugala, Deniyaya with an installed capacity of 24.8 MW. Detail studies are presently underway.

2.2 Site Location

The site is located in the Sabaragamuwa District approximately three hours driving time from Colombo.

2.3 Project Overview

The project under study was not identified by the CEB master plan but was located by Zyrex Power Company Limited in 1996 and an LOI was granted in the same year. Zyrex Power Company was involved in developing two other projects namely Rakwana Small Hydro Power Project and Delgoda Small Hydro Power Project with a total generation capacity of 3.2 MW. These two plants are now commissioned and grid connected. Parallel to the work undertaken to these two projects preliminary studies and work commenced under Erathna Small Hydro Power Project.

Taking into consideration the large potential energy generation of the Erathna Small Hydro Power Project and the investment in excess of Rs. 650 million, in 2001 it was decided that the project should be developed as a stand alone project entitling the project to benefit from special tariff increase of 15 % and related tax concessions for large scale infrastructure under the Board of Investment. Consequently with all the statutory approvals a new legal entity under purview of the BOI titled Zyrex Power Company Erathna Limited was incorporated towards the end of 2001. It is this company that has now undertaken the development of this project.

The catchment of this project consisting of 14.5 km2 although appears to be small in extent falls within the peak wilderness Natural Reserve and could therefore be considered a primary protected area. With the weir located at 840 m. MSL and power house at 377 m. MSL. The generation capacity using two twin jet Pelton turbines is 9 MW with an annual energy generation of 32.5 GWH.

The entire site including the access road to the weir runs through private lands and abandoned tea land belonging to the Land Reform Authority. The private land has been purchased and clearance by Land Reform Authority has been obtained.

The inter connection point is approximately 18 kms away from the powerhouse. This power line runs along the route taken by existing Sri Pada line and Erathna 33 KV supply line. This alleviated the necessity of complicated procedure of clearing way leaves.

3 Topography

3.1 Topographical Maps

Topographical Surveys of the Project Area is available to a scale of 1:50,000 with contour intervals of 20 metres in Sheet 68–Nuwara Eliya and to a scale of 1:10,000, with contour intervals of 10 metres in Sheet 68/16 prepared by the Survey Department of Sri Lanka. The latter has been prepared in 1993 by stereo compilation using 1:50,000 aerial photographs of 1981 and field checked in 1997. These survey maps were used for the initial conceptual development of the project.

3.2 River Topography

Kuru Ganga leaves the Peak Wilderness Sanctuary at an elevation of 1030 m. MSL and flows steeply west words till it reaches the village of Adavikanda at an elevation of 400 m. MSL. Close to the pilgrims rest called Maha Ambalama it forms the Manna-Kethi Falls from elevation 860 m. to 840 m. and thereafter flows on steep exposed bedrock to an elevation of 600 m. The riverbed below this level is covered with large boulders and the banks with thick vegetation.

3.3 River Valley

The river valley is steep and rises to an elevation of 1580 m. on the left bank and 1600 metres on the right bank with a number of escarpments. The valley is approximately 2.5 km. wide. The left bank comprises of thick virgin jungles of the Peak Wilderness. The right bank from the Maha Ambalama to Adavikanda village mainly comprises of abandoned tea land of the Warnagala and Clovasana Estates, now mainly scrubland and village settlements mostly at the lower elevations.

3.4 Access

There is no motorable road access beyond Adavikanda village The Adams Peak pilgrims trail runs close to the river with steps at steep sections and is illuminated during the pilgrimage season December to April. A 11,000 kV power line runs close to the trail. Terraced trails about 2 metres wide constructed for the tea plantations exists still in good condition but overgrown with shrub.

3.5 General Topography

The topographical maps indicate the following features:

i) The river flows steeply with river gradients over 15% down to 400 m. MSL and thereafter with milder gradients less than 10%,

ii) The terrain on the left bank is more uniform and milder in slope in comparison to the right bank, particularly below the Manna-Kethi Falls.

iii) On the right bank milder gradients are observed from elevation 900 m. to 530 m. and steeper gradients from 530 m. to 400 m.

3.6 Ground Surveys

A Topographical ground survey was carried out in 1996 on the left bank to a scale of 1:2000 with 5 metre contour intervals for the detail design of the project.

Detailed surveys were carried out for the weir, headrace channel, forebay, penstock trace, anchors and piers and the powerhouse area for the construction design of the project.

All project survey levels are in relation to a Datum El. 1000.00 m. established at the intake at which the absolute elevation is approximately 840 m. Mean Sea Level. As such all project levels have to be reduced by 160 m. to convert to MSL.

3.7 Access Road

In order to facilitate and financially optimize the movement of material, inspection of the total project and for other operational and maintenance purposes in the long term an access road has been built up to the forebay tank approximately 300 meters from the weir. This road commences from the powerhouse and will be approximately 4 km in length. The road has been done with compacted gravel with suitable drainage with rubble paving in more difficult sections. Culverts have been built at required points. Vegetation and storm water drains have been handled as appropriate to minimize erosion etc. and facilitate the maintenance of the road in long term.

3.8 Land

Total extent of land essential for the project is about 1.7 Ha. This extent covers the land trace from the weir through the channel up to the forebay and thereafter along the penstock path to the land on which powerhouse is located and through to the tailrace.

The ownership of critical area of land from weir to the powerhouse is vested with Land Reformed Authority, and private individuals. The ownership of the land trace of the road way also falls in to the same two categories.

4 Geology.

4.1 General Geology

The elevation of the project area varies from 400 m. MSL to 1000 m. MSL.

Geologically the project area belongs to the central part of the highland complex of Sri Lanka. The area comprises of high grade, lithologically and isotropically distinct metamorphic rocks of the Highland Complex.

Geomorphologically the area consists of steep V-shaped valleys, rock cliffs, cliff boulders having average sizes of 9" to 20', in-situ boulders and boulder trains. The slope directions and the slope angles vary considerably from place to place having an average angle of 40° . The presence of large intact boulders in the streams and in the valleys indicate that whole project area is located in a highly fractured zone.

Rock types of project area is mainly granulitic gneiss, mostly garnetiferous and charnockitic gneiss. The rock type and their direction vary considerably from place to place. The foliation plane is well defined and the whole area is striking 20 ° to 35° from the North. Dip angles and direction of joints varies from place to place within the range of 15° to 50° , and 40° to 135° respectively. Most joints are tight enough, however there are some joints with few centimeter separation. No secondary minerals or clay filled joints can be seen. Most of the rock faces are eroded due to water flow.

4.2 Overburden Deposits

Types of overburden deposits and their thickness vary considerably from place to place due to the inherent nature of the area. In the upper part of the slopes, rocky cliffs can be found. These cliffs have been formed along the major joint systems and hence the middle and the lower part of the slopes consist of colluvium soils and boulder deposits overlain by residual deposits. But in some areas residual deposits can be found associated with the weathered rock. Mainly, all the stream outlets consist of massive boulders, which have fallen from the upper area. Rock exposures associated with the stream segments and water path show the high erosional capacity in the area by these streams.

4.3 Weir site

Bedrock of Feldspathic Gneiss with Garnets is well exposed along the Kuru Ganga at the proposed weir site. Two almost vertical joint sets striking 90/V, 180/V and well defined foliation planes are observed with spacing between the joints 0.3 m and 0.5 m. respectively.

Exposed bed rock at the surface in the river section and also at the right abutment is fresh to moderately weathered. However, at the left abutment of weir site, rock mass is affected by weathering along the joints. As a result the left bank area is covered with detached rock blocks and in-situ boulders. Due to non availability of proper access for earth moving machinery to left bank, it may not possible to remove unstable detached rock/boulders at the left abutment. Hence it is recommended to consolidate the left abutment detached rock blocks by using rock dowels and also by filling open joints and voids with concrete.

4.4 Head Race Channel

The 280 m stretch of head race channel lies on over burden and highly weathered rock. The excavated testpits indicate material consisting of brownish lateretic clayey sand with gravel. In some places weathered rock will be encountered.

It is recommended to provide an adequate drainage system to drain storm surface water away from the excavated slopes to avoid minor failures and also to turf exposed slopes to prevent surface erosion.

4.5 Forebay

The forebay area is covered with thin overburden/vegetation. Bed rock is exposed along the stream runs in the vicinity of the forebay. It could be assumed that bed rock level is not deeper than 1m at the foundations of the forebay.

4.6 Penstock

Entire Penstock path lies on a highly fractured zone where rock cliff, boulder deposits overlain by residual deposits, and residual deposit associated with the weathered rock can be found.

Rock types and their direction vary considerably from place to place. Strike of the rock varies from 22° to 305° from the North. Dip angle varies from 15° to 50° towards different directions as shown in the table below:

Location	**Strike/Dip**	**Joints**	**Rock Type**
A. LHS of Maha Oya	45/20W	100/V,4/m	Feldspathic Quartzite
B. Upstream of A	60/27W	-	Weathered rock
C. RHS of Weti Ela	22/50W	320/60NBE-8/m 80/60S-5/m	Garnetiferous . Quartzo Feldspathic Gneiss
D. Upstream of C	20/21W		-do- Weathered
E. Upstream of D	No bed rock exposures		
F. Upstream of E	305/25E	100V-12/m 350/V-8/m	-do-

In the upper slopes of the penstock line, cliffs had been formed due to the presence of major joint systems that is almost in the direction of East-West.

Soil samples taken from the penstock trace showed the following characteristics:

Sample No.	1	2	3	4	5
Classification	SC	SM	SM	SM	SM
Liquid Limits	53				
Plastic Limits	36				
Plastic Index`	16				
Gravel %	2	1	5	2	8
Sand %	59	63	61	77	75
Silt & Clay %	39	36	34	21	17
Clay %	16	20	23	15	11

Sample No. 6

Cu kPa	19
θ	20

As the Penstock path lies on a highly fractured zone where rock cliff, boulder deposits overlain by residual deposits, and residual deposit associated with the weathered rock can be found the positions of anchor and pier foundations should be selected carefully to avoid any failures. In the process of the selection of foundations for penstock anchors and piers the following have been recommended.

i) In places having thin overburden, foundation of the anchors/piers should be located on the bed rock after removing the overburden.

ii) In places having detached rock block/insitu boulders foundation of the piers should be located on these rocks after consolidation of the rock mass by injecting concrete in to openings/voids which were created due to weathering along the joints.

iii) In places with thick overburden the pier foundations of penstock may be located within the soil mass after adequate mechanical compaction. The risk of undermining of the foundation of the anchors and piers could be avoided by providing proper rubble masonry protection at the toe of the foundation.

iv) All unstable boulders above the penstock line should be removed before erection of the penstock line.

iv) After construction a geotechnical evaluation should be made of the anchor and pier foundations for ground conditions, surface water movement, slope erosion and undermining and suitable drains, paving, retaining walls, other protective measures and turfing to be carried out.

Most of the recommendations were implemented.

4.7 Power House

The entire area is covered with massive in situ boulders in thick colluvium deposits. However the visual inspections on areas where topsoil is removed and geomorphological features of the area indicate that sound rock level can be found at shallow depth. The rock type encountered in the area is biotitic gneiss with granite. These rocks have formed a sound foundation for the powerhouse. 6 bore holes were drilled and samples analysis was done. Design of the powerhouse foundations was based of theses analysis results.

A cross section of the hill slope at the powerhouse was analyzed using Stab-Lg software which gave a Factor of safety of 1.79.

4.8 Geo-technical Assessment

The project area, in general is not likely to be unstable to create unforeseen major geological failures.

5. Hydrology

5.1 General

The Erathna Small Hydropower Project has a catchment area of 14.5 sq. km. extending from 840 metres above MSL to 2100 metres MSL receiving an annual average rainfall of 4841 mm. The catchment area extends up to the Adams Peak and lies solely within the Peak Wilderness Sanctuary.

5.2 Analysis of Stream Hydrology

A hydrological study was carried out for the project to determine the availability of water at the project site in terms of seasonal and monthly variation on long term basis. A mathematical model correlating daily rainfall data with daily stream flow was developed and the daily flows generated for a period of 29 years from 1967 to 1996.

5.3 Hydrological data

There are no rain gauges or stream flow measuring stations or any other hydrological instrumentation in the catchment. The only known rain gauge in Kuru Ganga catchment is at Keragala, located on the right bank of Kuru Ganga and below Eratna and it has long term rainfall data. There are few raingauges in adjoining catchments with long term records and average annual rainfall estimates of these gauges are given below.

Station	River	Elevation	Period of Record	Average Annual Rainfall
Keragala	Kuru Ganga	150 m.	1969 to 1996	4717 mm
Carney	Kalu Ganga	305 m.	1949 to 1985	4413 mm
Maliboda	Seethawaka Ganga	274 m.	1965 to 1995	4769 mm
Alupola	Kalu Ganga	543 m	1949 to 1985	4483 mm

The only raingauge within the Kuru Ganga catchment, Keragala shows a similar annual rainfall in comparison to the other rain gauges in this region and is predominately influenced by the South West monsoonal rains. Therefore Keragala rainfall was considered to represent Kuru Ganga upper catchment and was used in stream flow data generation. The Rainfall at Keragala is given in Table 5.1.

Regarding the stream flow data, the nearest stream flow measuring station within Kalu Ganga catchment is located at Ratnapura, which intercepts 603.0 sq.km. This is two large for interpolation as the catchment under the study is only 2 .1 % of Ratnapura catchment. There had been an another stream flow measuring station at Lellupitiya across Denawaka Ganga which intercepted 76.0 sq.km of Kalu Ganga catchment. The data had been collected for a period of only 8 years and therefore too short. However this data can be made use for a cross check as the catchment is small.

There is a gauging station with a smaller catchment in the adjoining river basin and it is located at Deraniyagala in Seethawaka Ganga and this gauging station intercepts a drainage area of 183 sq.km. Daily flow records are available since 1948 at this station. The topography, geology and land use are similar to the Kuru Ganga catchment and therefore this catchment was used to model the behavior of Kuru Ganga as there is no other alternative.

There is no evaporation pan in close proximity to the catchment. In order to estimate the evaporation and evapo-transpiration losses in this area, observed pan evaporation data for a period of 10 years at Ratnapura was taken. As the variability of evaporation from one location to another location is not very much abrupt in comparison to other hydrological variables such as rainfall, average monthly evaporation rates were taken from Ratnapura.

5.4 Methodology

Deraniyagala is the only gauged catchment which is similar to the project site in topography, land use and geology. Therefore a rainfall runoff model was developed to simulate stream flow from rainfall from the most recent observations in Deraniyagala.

Rainfall data are available in Maliboda and Dabar Divisions for a considerably long period. Dabar rainfall was found to be more suited for the Deraniyagala catchment in comparison to Maliboda. Therefore Dabar rainfall was used in model development.

The correlation of daily rainfall and evaporation with the corresponding stream flow rate, when expressed in the form of a mathematical relationship is called a hydrological model. There are different types of hydrological models and model structures. About 10 such models were examined for the hydrological data available at Deraniyagala. From the comparison of estimated model efficiencies of these models, a conceptual model developed by a Chinese hydrologist Zhao was found to be the best and was selected to represent the catchment of Deraniyagala.

5.5 Mathematical Model

This model is called the Xinanjiang model, which was developed in 1973 by Zhao. For the development of the model, daily hydrological data from October 1990 for 1200 days were used. For the verification of the model, balance days of data series up to September 1996 were used. The efficiency of the model in calibration was found to be 63.17% and that of model in verification was 64.01%. This percentage is an indication of the degree of fitness of the model to the observed data.

The estimated model parameters obtained by the optimization technique are given below.

WM = 203 - Maximum soil moisture
X = 0.264 - Factor to convert upper zone flow
Y = 0.780 - Factor to convert lower zone flow
KE = 2.01 - Factor to represent evaporation and other interception losses
B = 5.67 - Distribution index
FC = 40.0 - Infiltration
IMP = 0.22 - Imperviousness of the catchment
C = 0.736 - Evaporation from lower soil layers
N = 2.3 - Nash N
NK = 0.71 - Nash NK
KG = 80.7 - Ground water

5.6 Discharge Measurements

There are no discharge measurements available at the site and therefore one discharge measurement was carried out during the study period. Conventional current metering of the river flow was done near the bridge site at Erathna as it is the only acceptable site for such flow measurements.

5.7 Data Generation

The Xinanjiang model developed for Deraniyagala flow measuring site was used at Erathna to generate stream flow data from 29 years of rainfall at Keragala. Daily rainfall data for 29 years from 1967 to 1996 were used to generate data. Table 5.2 gives the 29 year estimated mean monthly streamflow from daily stream flow generation.

From the long term rainfall used for stream flow generation it was found that the average annual rainfall is 4841 mm. This input rainfall to the model together with evaporation data at Ratnapura produced an average runoff of 2790 mm, which has a runoff rainfall ratio of 58 %.

5.8 Flow Duration Curve

Flow duration curve provides the vital information to plan and design the plant capacity of a hydropower project. In this study flow duration curve for an average year is given in Figure 5.1 from average data generated from the model.

5.9 Flood Study

The catchment of the Erathna Small Hydropower Project is relatively small (14.5 sq.km). Snyders synthetic flood hydrograph technique was used for estimating the flood peaks, which gives more realistic flood peak values than the Rational formula for very small catchments. Length of stream up to the location of the weir is about 6.8 km. with an average slope of about 17%. Time of concentration of the catchment is about 1.5 hours. According to Snyders parameters, time to peak is about 4.5 hours for a storm of 1.5 hour duration.

Flood peaks for different return periods are given below:

Return Period (Years)	Flood Peak (cumecs)
10	56
100	85

5.10 Summary

Following is a summary of hydrological information gathered from measured data and hydrological inferences drawn from the generated data.

1.Average annual rainfall	4841 mm
2.Average annual evaporation	1238 mm
3.Annual average runoff from generated data	2790 mm
4.Runoff-rainfall ratio	58%
5.Annual average flow volumes	36.3 M.C.M.
6.Average daily flow rate from generated data	1.30 cumecs
7. Maximum daily flow rate from Average	2.89 cumecs
8. Minimum daily flow rate from Average	0.43 cumecs
9. Flood Peak (100 year return)	85 cumecs

5.11 Further Studies

With the construction of the weir in February-March 2002, daily flow measurements at the weir have been carried out. Daily rainfall at the weir site and the powerhouse site have also been taken from February 2002.

A further hydrology study with the additional data and an evaluation of the hydrology is currently underway. A report covering the period up to June 2002 is expected to be completed by mid- September 2002. It is considered that this report will give reliable flow data as they will be based on actual rainfall in the catchment area and measured flows at the weir site.

Table 5.1
Rainfall at Keragala

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1967	195	146	245	296	318	801	390	347	249	784	491	302	4564
1968	137	37	235	561	473	889	421	213	647	560	375	249	4797
1969	123	137	58	752	1088	459	55	267	305	1176	304	292	5016
1970	203	132	331	621	366	544	459	381	356	732	287	97	4509
1971	225	119	235	492	589	505	371	587	980	551	439	307	5400
1972	60	66	112	554	656	547	322	285	616	819	401	143	4581
1973	63	148	344	551	546	694	446	295	215	431	427	284	4444
1974	4	194	258	593	615	553	862	195	780	215	47	147	4463
1975	78	167	135	391	670	639	180	357	341	666	696	220	4540
1976	96	46	285	490	296	202	351	363	195	594	361	370	3649
1977	42	151	223	458	874	601	151	326	379	713	480	356	4754
1978	250	169	240	447	1116	310	286	297	272	530	229	149	4295
1979	75	275	151	267	388	540	396	83	859	556	407	373	4370
1980	22	43	165	673	687	305	304	478	349	384	379	346	4135
1981	74	57	407	327	356	362	377	152	470	248	491	204	3525
1982	22	0	279	405	285	926	508	459	291	611	652	252	4690
1983	28	56	154	169	735	339	240	562	696	371	283	532	4165
1984	368	345	345	706	898	715	418	53	449	263	708	71	5339
1985	491	214	435	188	826	1010	345	336	434	761	535	461	6036
1986	143	479	331	446	569	710	463	561	1532	1247	421	460	7362
1987	283	38	197	352	628	407	23	726	435	956	676	350	5071
1988	32	590	554	899	1077	737	772	828	902	247	489	147	7274
1989	83	9	248	421	908	1163	963	436	643	955	536	217	6582
1990	192	144	391	464	801	383	413	94	187	534	462	322	4387
1991	347	137	230	363	588	640	356	384	152	673	434	144	4448
1992	93	0	65	441	500	363	479	393	423	535	534	117	3943
1993	33	98	185	403	855	434	226	161	715	776	465	313	4664
1994	194	135	180	420	750	203	297	271	414	659	503	81	4107
1995	192	190	231	551	1015	717	255	601	434	638	404	45	5273
Mean	143	149	250	472	671	576	384	362	508	627	445	253	4841

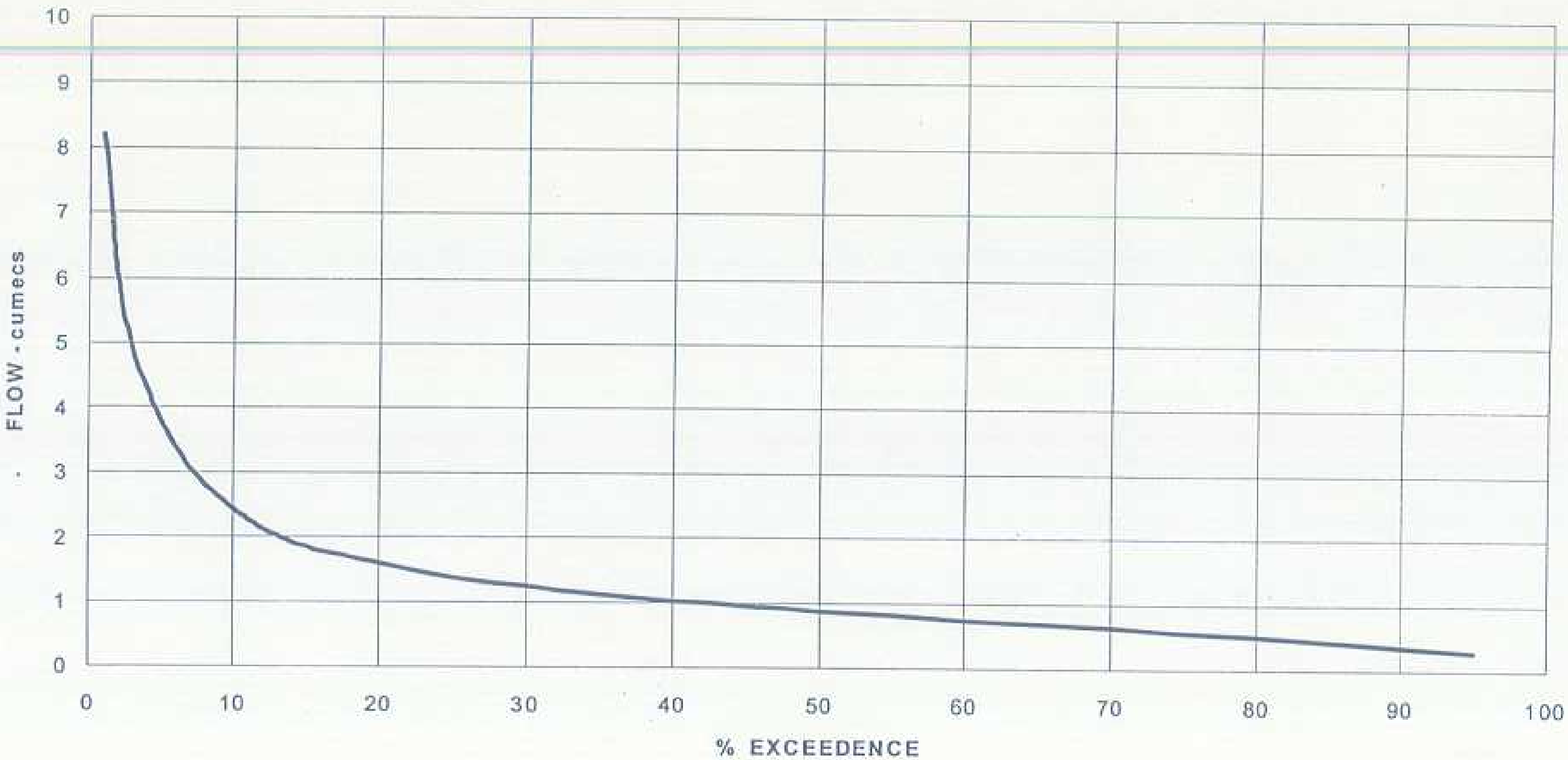
Table 5.2

ERATHNA SMALL HYDROPOWER PROJECT

Mean Monthly Flow - cumecs

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Mean
67/68	2.13	1.04	0.86	0.71	0.38	0.37	1.02	1.02	2.90	1.41	0.98	1.67	1.21
68/69	1.98	1.71	1.13	0.74	0.54	0.36	1.47	3.33	1.65	1.00	0.85	0.90	1.31
69/70	4.16	1.18	1.18	0.88	0.49	0.64	1.28	0.86	1.47	1.47	1.47	1.17	1.35
70/71	2.10	1.27	0.81	0.70	0.50	8.45	0.75	1.36	1.47	1.17	2.34	3.06	2.00
71/72	2.30	2.12	1.35	0.75	0.56	0.40	0.87	2.03	1.88	1.07	1.03	1.62	1.33
72/73	2.47	1.82	1.04	0.71	0.64	0.68	1.31	1.41	1.74	1.59	1.39	0.89	1.31
73/74	1.16	1.50	0.91	0.54	0.52	0.49	1.25	1.40	1.56	2.87	1.23	2.12	1.30
74/75	1.63	0.81	0.63	0.43	0.36	0.33	0.47	1.66	1.70	0.85	0.87	1.11	0.90
75/76	1.13	1.53	1.08	0.70	0.50	0.53	0.78	0.68	0.50	0.80	0.88	0.50	0.80
76/77	1.22	0.95	1.10	0.66	0.55	0.44	0.85	1.60	2.45	1.03	0.99	1.14	1.08
77/78	2.24	1.90	1.30	1.10	0.71	0.58	1.02	3.14	1.17	1.11	0.81	0.87	1.33
78/79	1.44	0.82	0.62	0.42	0.52	0.31	0.39	0.68	1.50	0.94	0.48	1.95	0.84
79/80	1.86	1.31	1.38	0.73	0.54	0.44	1.34	1.75	1.26	1.08	1.23	1.10	1.17
80/81	1.27	1.03	1.09	0.83	0.47	0.73	0.73	0.76	0.86	1.17	0.51	1.07	0.88
81/82	0.69	1.69	0.84	0.35	0.23	0.38	0.66	0.45	2.92	1.34	1.47	1.13	1.01
82/83	1.87	2.08	1.52	0.82	0.60	0.59	0.44	1.45	0.93	0.77	1.59	2.16	1.23
83/84	0.39	0.66	0.94	0.41	0.93	0.82	1.52	2.65	2.27	2.17	1.18	1.43	1.28
84/85	1.11	2.12	0.86	1.24	0.90	1.06	0.64	1.87	3.21	1.55	1.67	1.42	1.47
85/86	2.18	2.26	1.86	1.11	1.39	0.99	1.12	1.85	2.44	1.29	2.04	4.88	1.95
86/87	4.67	2.75	2.35	1.72	1.13	0.95	0.85	1.66	1.63	0.60	1.42	1.39	1.76
87/88	3.05	2.60	1.70	0.98	1.71	1.78	2.75	4.74	2.08	3.26	3.16	3.59	2.62
88/89	1.89	2.27	1.21	0.83	0.54	0.79	0.71	2.15	4.27	3.65	2.34	2.36	1.92
89/90	3.42	2.63	1.70	1.26	0.85	0.85	0.99	2.41	1.35	1.36	0.85	0.69	1.53
90/91	0.98	1.25	0.62	1.19	0.78	0.62	0.77	1.18	1.55	1.26	1.38	0.85	1.04
91/92	1.10	1.05	0.69	0.51	0.30	0.25	0.64	1.14	1.18	1.11	1.07	1.14	0.85
92/93	1.69	1.99	0.87	0.56	0.43	0.38	0.64	1.82	1.81	0.86	0.61	2.08	1.15
93/94	2.55	1.32	1.39	0.95	0.63	0.51	0.75	1.64	0.91	0.79	0.80	1.06	1.11
94/95	1.75	1.52	1.04	0.78	0.60	0.55	1.12	2.69	2.11	1.42	1.78	1.72	1.42
95/96	2.77	1.54	0.88	0.63	0.49	0.35	0.83	0.31	1.57	1.04	0.58	1.48	1.04
Mean	1.97	1.61	1.14	0.80	0.65	0.88	0.96	1.71	1.80	1.38	1.28	1.60	1.32

ERATHNA SMALL HYDROPOWER PROJECT
FLOW DURATION CURVE



6. Environmental Aspects

Erathna Small Hydro Power Project had not been identified in the CEB master plan or any other developer prior to its identification by Zyrex . Initially an application was made to the CEB for the development of this project with the weir site located upstream of waterfall called Manna-Kethi Falls. Due to concerns expressed by Sabaragamuwa Provincial Council it was decided to move the weir site below the falls.

On the above basis and after having completed an in depth flora and fauna study, as well as an environmental study, the required clearance was obtained from the Central Environmental Authority for the construction of the project on the right bank for the capacity of 8.4 MW. Subsequently actual flow measurement and project and plant optimization indicated that the capacity could be increased to 9.9 MW. The Central Environmental Authority clearance has been obtained for this upgrade with the concurrence of the CEB.

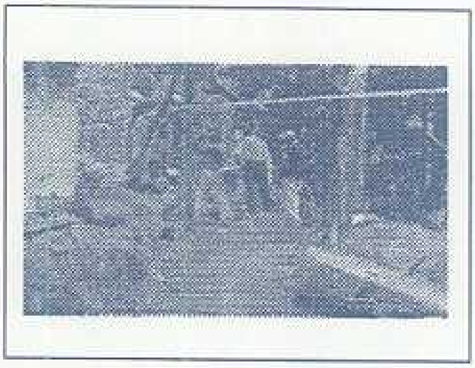
Waterfall Mannakethi Ella

The project includes the construction of 4 km long access road from powerhouse area to forebay tank. This road has been constructed and it provides access to a remote village called Halgastenna in which 10 families live. The foot path that villagers used prior to construction of the access road is very steep and people in this village faced tremendous difficulties when they became ill.

The project requires relocation of two families and these two families accepted the compensation packages offered to them.

Family benefited from new road

A detailed environmental study based on the Term of Reference issued by the Central Environmental Authority was carried out and the requisite approval was obtained.



A house affected by the project

7. Project Alternatives

The following Project Alternatives were initially considered and evaluated for the conceptual development of the Project.

7.1 Right Bank Development vs Left Bank Development.

The terrain on the left bank of Kuru Ganga is more uniform and milder in slope in comparison to the right bank, particularly below the Manna-Kethi Falls. The penstock length would also be shorter. However there are two distinct disadvantages of a development on the left bank. The left bank is covered with a luxuriant tropical forest and considerable environmental damage would be caused by the construction of access roads, headrace channel and the penstock. A development on the left bank would also entail the construction of a major bridge across Kuru Ganga at Adavikanda and an access road through thick jungle.

In comparison though the terrain is steeper and uneven the right bank is mostly of scrubland. The access road could be traced through the terraces of the abandoned tea estate. The road would also benefit the villagers and in time would be used by the pilgrims. The present pilgrims trail would also fascilitate initial construction work and transport of materials.

As such the development of the Project on the Right bank was selected.

7.2 Location of the Weir

The upper catchment of the Kuru Ganga is in the Peak Wilderness Sanctuary - a protected jungle reservation. The river leaves the boundary of the sanctuary at elevation 1030m. MSL. A picturesque waterfall called Manna-Kethi Falls is at elevation 840 to 860 m.

In order to obtain the maximum head, a weir location upstream of the Manna-Kethi falls but downstream of the sanctuary was considered which would have adversely affected the falls particularly during the pilgrim season. Objections to the impairment of the falls were raised by the Local Authorities - The Divisional Secretary and after discussions it was agreed to preserve the falls by locating the weir downstream of the falls. The weir top level was decided at 840 metres MSL. The weir will form a shallow pool below the falls which will enhance the beauty of the falls and will also form a recreational area.

7.3 Location of the Powerhouse

The installed capacity and the energy generation of a project is directly proportional to the flow and the available head. As the cost of the project will depend on the length of the water conveyance system, the river gradient is an indicator of the intrinsic viability of the development of that stretch of the river.

The river bed levels and the slopes from the boundary of the Peak Wilderness Sanctuary to Adavikanda village is given in Table 7.1 below.

Table 7.1

Station metres	River Bed El. m. MSL	River Bed Slope	Overall Slope
0	1000		
220	950	0.227	0.227
500	900	0.179	0.220
660	850	0.313	0.227
900	800	0.208	0.222
1080	750	0.278	0.231
1280	700	0.250	0.234
1410	650	0.385	0.248
1580	600	0.294	0.253
1780	550	0.250	0.253
2060	500	0.179	0.243
2760	450	0.185	0.236
3040	400	0.132	0.221
3620	350	0.086	0.198
4220	300	0.083	0.180

The upper reaches of the river has a gradient 38% to 18% which markedly reduces to 13% below 400 m. MSL. An optimisation study indicated that below this location the capitalized value of the gain in energy do not justify the extra investment of the penstock length The river is at 400 m. MSL at Adavikanda village where the existing motorable road from Eratna ends and the foot climb on the Pilgrims Trail starts. A suitable location for the powerhouse was selected at this location at the foot of the mountain with easy road access for heavy powerhouse equipment. The river level at this location is at 370 m. MSL.

7.4 Single vs. Two Stage Development.

Due to the available high head of 462 metres and the long penstock the alternatves of a single stage and two stage development was evaluated. A suitable location for the intermediate powerhouse was found at Jambolagaha Ambalama at an elevation of 600 m. MSL.

A two stage development with the intermediate powerhouse at Jambolagaha Ambalama will have the advantages of a phased out development and the additional generation of energy due to the flow from the intermediate catchment. However it will have the following disadvantages:

- The capital cost of a two stage development will be higher due to the duplication of an intake, headrace channel, forebay, powerhouse and a switchyard.
- An intermediate powerhouse will require the construction of a good road to transport powerhouse equipment and transformers.
- The power line has to be extended up to the intermediate powerhouse.

As there was no major constraint on the funding, and preliminary estimates indicated that the higher capital cost of a two stage development off sets the additional income due to the enhanced generation of energy, the development of the power potential with a single stage development was decided upon.

7.5 Layout of the Water Conveyance System

Following investigations were carried out to determine the most economical water conveyance system and the path.

i) Topographical surveys on the left bank to a scale of 1:2000 with 5 metre contour intervals. -1996
ii) Project Study by Central Engineering Consultancy Bureau for the conveyance system – October 1997
iii) Investigations on Slope Stability by Landslide Studies and Services Division of National Building Research Organisation – December 2000
iv) Further Investigations on Slope Stability by Landslide Studies and Services Division of National Building Research Organisation – March 2001
v) Cadestal survey of land ownership

The water conveyance path was selected based on the following factors.

In general the unit cost and the friction gradient of a head race channel is much lower than that of a penstock. However the channel being a free flow structure has to traverse on a contour with a low gradient. The initial section of the water conveyance system is a channel limited in length to 280 metres as any further continuation would take the flow away from the destination. Further the end of the channel is a massive slope of bed rock with thin soil cover less than a metre ideally suitable for the construction of the forebay tank.

To be cost effective the initial length of the penstock has to be under low pressure and the high pressure section which has to be of thicker plate should be kept as short as possible. However a drop of 190 metres in the initial 475 metre length of the penstock had to be accommodated to align the penstock in the direction of the powerhouse. The next 1200 metre length of penstock runs on a mild gradient dropping only 120 metres but traverses over deep streams necessitating high piers and longer spans. The final section of the penstock is steep and drops 165 metres over a length of 500 metres and negotiates a steep terrain with escarpments.

The preliminary penstock trace was set out on ground with anchor and pier positions and inspected and adjusted where necessary for safe foundation conditions, slope stability, minimum excavation, minimum height of piers and to avoid streams.

8. Plant Sizing and Optimization

8.1 General

Plant sizing and optimization is an iteration process of initially determining a trial plant capacity, optimizing the channel size and the penstock sizes for that capacity and thereafter optimizing the plant capacity for the optimized channel and penstock and repeating the iteration process till the incremental change is insignificant.

8.2 Penstock Optimisation

The pipe diameter was optimized for upper, mid-upper, mid-lower and lower sections and the results are given in Table 8.1.

8.3 Power Generation

Power generation was computed on the following formula:

Power Generation KW = 9.81* Efficiency*Gross Head*Flow

Efficiency is the combined efficiency of the penstock, Turbine and the Generator for the flow.

Efficiency of the penstock = (Gross Head- Friction Head)/Gross Head

Efficiency of the Turbine and Generator was based on the efficiency figures given by a plant supplier,

The efficiency figures used based on penstock losses, and operation of two turbines to obtain maximum plant efficiency is given overleaf as Table of Combined Efficiency.

Gross head is the hydrostatic head from the forebay to the turbine jets in metres. The gross hydrostatic head of the project is 462 metres.

Flow is the flow in cumecs.

Table of Combined Efficiency.

Flow % of Maximum	Penstock Efficiency	Plant Efficiency	Combined Efficiency
0	1.00	0.00	0.00
5	1.00	0.00	0.00
10	0.99	0.83	0.82
15	0.99	0.83	0.82
20	0.98	0.87	0.85
25	0.98	0.87	0.85
30	0.98	0.88	0.86
35	0.97	0.88	0.86
40	0.97	0.88	0.86
45	0.96	0.88	0.85
50	0.96	0.88	0.85
55	0.96	0.88	0.84
60	0.95	0.88	0.84
65	0.95	0.88	0.83
70	0.95	0.88	0.83
75	0.94	0.88	0.83
80	0.94	0.88	0.82
85	0.93	0.88	0.82
90	0.93	0.88	0.82
95	0.93	0.87	0.82
100	0.92	0.87	0.80

8.4 Energy Generation

The Mean Annual Energy Generation for various Plant Capacities based on the Flow Duration Table is given in Table 8.2.

The Mean annual Energy Generation was also calculated for various Plant Capacities using daily flows generated by the Hydrology Model. Results are given below:

Plant Capacity Kw	Rated Flow cumecs	Plant Factor	Average Annual Energy GWH
6000	1.63	0.60	31.57
7000	1.91	0.54	33.11
8000	2.18	0.49	34.30
9000	2.45	0.45	35.26
10000	2.72	0.41	36.01
11000	3.00	0.38	36.60
12000	3.27	0.35	37.07

The Energy Generation based on the Flow Duration Table differs from the Energy Generation computed by daily flows by about 2 percent due to the indirectness of the method.

8.5 Net Energy Generation

The daily flows generated by the hydrology model are average daily values. As such the fluctuations of the flow within the day are not taken into account in the available flow for generation. While the flow available for generation during heavy rains will be limited to the rated flow, at other times a correction have to be applied for flood peaks.

A hydrology study conducted by the hourly measurement of stream flows in a similar catchment was used to estimate this correction. Power generation studies made on the basis of hourly flows and daily average flows showed a reduction of about 5 percent of energy generation when hourly flows were used.

The transformer efficiency is assumed to be 98.5 %.

An overall correction factor of 0.9 is applied to adjust for peak flows, transformer efficiency and possible CEB outages to arrive at the Net Mean Annual Generation of Energy.

8.6 Optimised Plant Capacity

At a capacity of 10,000 KW following are the incremental costs of equipment and penstock for increase and decrease of capacity.

Equipment	Rs. 15 millions/Mw
Penstock & Civil	Rs. 5 millions/Mw
Total	Rs. 20 millions/Mw

Based on an energy price of Rs 5.65/Kwh following are the Net Present Values at discount rates of 15 per cent and 20 per cent. For plant capacities 8,000 KW to 12,000 KW.

Installed Capacity (KW)	Energy Generation GWH	Project Cost (Million Rs.)	NPV @ 15% (Mil Rs)	NPV @ 20% (Mil Rs)
8000	30.9	560	358.14	246.38
9000	31.7	580	365.67	251.02
10000	32.4	600	367.82	251.41
11000	32.9	620	366.29	248.89
12000	33.4	640	361.37	243.68

Based on the above an installed capacity of 10 MW is the most economical installation.

However as approval for grid connected small hydropower projects is given for capacities less than 10 MW, an installed capacity of 9.9 MW was decided.

8.7 Mean Annual Energy Generation

The net Mean Annual Energy Generation for a plant of capacity 9.9 MW based on the daily flow generated by the hydrology study for the period 1967 to 1996 is 32.3 GWH.

The monthly, annual and mean annual Net Generation is given in Table 8.3

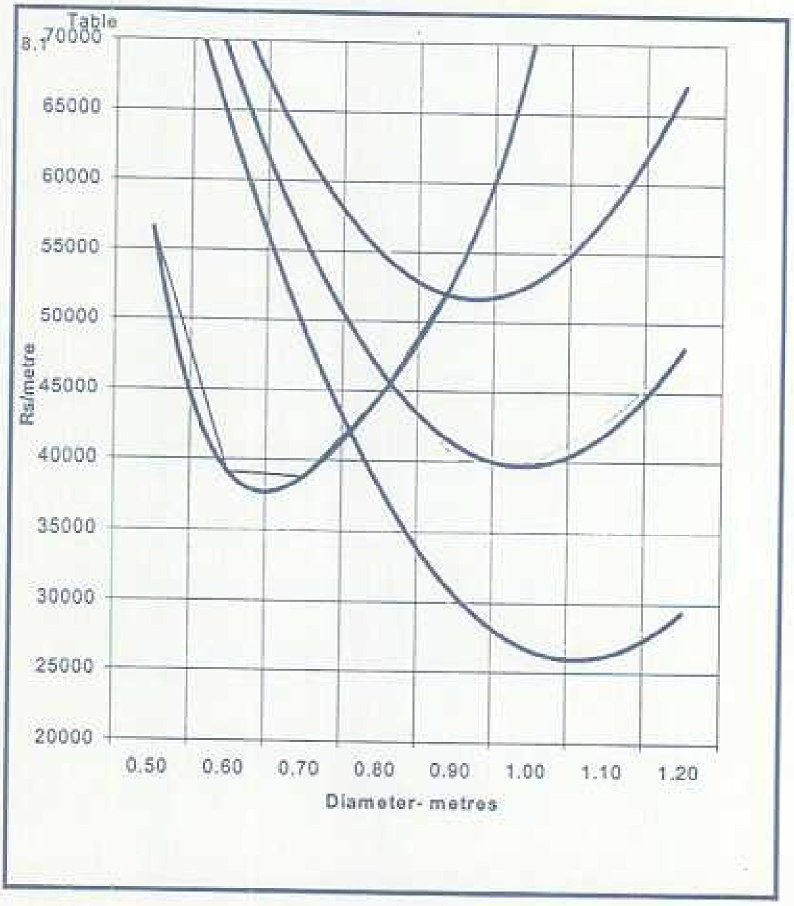
8.8 Benefits of Clean Development Mechanism (CDM)

This Project will be eligible for registration as a CDM Project and such registration will enable the Project to market Carbon Credits. This will further improve the viability of the Project. At this point of time the detailed information is not widely available to ascertain the estimated revenue generation and, therefore, such additional cash flows were not taken into feasibility analyses. However, such additional cash flows will cushion any impairment of cash flows resulting from a prolonged drought situation in the project catchments areas.

Table 8.1

ERATHNA MINI HYDROPOWER PROJECT
PENSTOCK
ECONOMIC DIAMETER

Internal diameter metres.	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
Total Cost Rs/metre								
A-Upper Section				38651	29556	26777	27022	28890
B-Mid-upper Section				47028	40159	39867	42861	47739
C-Mid-lower section				55405	50761	52957	58699	66588
D-Lower Section (one pipe)	56531	39072	38789	44624	53419			



ERATNA SMALL HYDROPOWER PROJECT

Energy Generation

Based on Flow Duration Table

Table 8.2

Plant Capacity KW	6000	7000	8000	9000	10000	11000	12000
Max. Flow cumecs	1.63	1.91	2.18	2.45	2.72	3.00	3.27

Flow Duration %	Flow cumecs	Energy 1000 KWH						
1	8.20	526	613	701	788	876	964	1051
2	6.00	526	613	701	788	876	964	1051
3	4.90	526	613	701	788	876	964	1051
4	4.30	526	613	701	788	876	964	1051
5	3.80	526	613	701	788	876	964	1051
6	3.40	526	613	701	788	876	964	962
7	3.06	526	613	701	788	876	924	957
8	2.82	526	613	701	788	847	884	884
9	2.61	526	613	701	788	812	822	832
10	2.44	526	613	701	761	770	770	779
11	2.29	526	613	686	721	721	730	730
12	2.14	526	613	669	677	685	685	685
13	2.02	526	613	643	643	651	651	659
14	1.93	526	597	615	623	623	630	630
15	1.85	2568	2774	2808	2842	2842	2876	2876
20	1.60	2404	2434	2463	2463	2493	2523	2523
25	1.39	2141	2167	2193	2193	2219	2219	2245
30	1.24	1952	1952	1976	2000	2000	2023	2023
35	1.13	1779	1801	1822	1822	1844	1844	1844
40	1.03	1651	1670	1670	1690	1690	1690	1690
45	0.95	1526	1544	1562	1562	1562	1562	1544
50	0.88	1426	1426	1443	1443	1443	1426	1426
55	0.81	1316	1332	1332	1332	1316	1316	1316
60	0.75	1215	1229	1229	1229	1215	1215	1215
65	0.69	1127	1127	1127	1114	1114	1114	1114
70	0.63	1024	1024	1012	1012	1012	1012	1000
75	0.57	922	911	911	911	911	900	900
80	0.51	811	801	801	801	792	792	792
85	0.44	683	683	683	675	675	659	659
90	0.37	565	559	559	559	545	545	545
95	0.30	442	442	431	431	431	431	0
100	0.23							
MEAN ANNUAL ENERGY GWH		30.9	32.4	33.6	34.6	35.3	36.0	36.1

ERATNA SMALL HYDROPOWER PROJECT

Mean Annual Energy Generation - 9.9 MW Plant

Table 8.3

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
67/68	1.95	2.48	2.23	1.73	0.89	0.79	2.30	1.91	4.12	3.04	2.56	3.53	26.13
68/69	3.87	3.54	2.89	1.93	1.25	0.87	3.31	4.79	4.08	2.62	2.21	2.21	33.58
69/70	3.83	2.48	2.62	1.91	1.13	1.51	2.69	2.22	2.99	3.40	3.52	2.94	31.23
70/71	4.61	3.17	2.10	1.81	1.14	0.24	1.80	3.03	2.78	2.92	3.25	3.99	30.84
71/72	4.26	3.98	3.24	1.95	1.36	1.01	2.17	3.41	3.44	2.69	2.60	3.35	33.46
72/73	4.78	4.10	2.72	1.85	1.48	1.62	2.56	2.93	4.03	3.63	3.09	2.23	35.01
73/74	2.73	3.15	2.36	1.40	1.19	1.22	2.05	3.09	3.36	4.35	3.19	4.52	32.63
74/75	3.38	2.04	1.63	1.09	0.62	0.45	1.02	2.76	3.49	2.22	2.22	2.59	23.51
75/76	1.73	3.71	2.80	1.83	1.19	1.37	1.95	1.63	1.24	1.84	1.78	1.24	22.30
76/77	3.01	2.40	2.84	1.71	1.28	1.11	1.60	3.75	4.18	2.69	2.55	2.40	29.52
77/78	3.75	3.44	3.14	2.56	1.66	1.50	1.92	4.02	2.90	2.68	2.11	1.91	31.59
78/79	2.82	2.06	1.59	1.06	1.17	0.29	0.69	1.24	1.82	2.22	1.22	3.95	20.13
79/80	3.48	3.24	3.42	1.90	1.31	1.12	3.17	3.50	2.79	2.61	3.06	2.47	32.08
80/81	3.00	2.60	2.63	1.97	1.09	1.81	1.80	1.95	2.15	2.17	1.32	2.31	24.80
81/82	1.78	2.69	1.66	0.88	0.02	0.66	1.36	0.89	3.81	3.46	3.78	2.84	23.81
82/83	3.90	4.38	3.60	2.14	1.39	1.47	1.00	3.71	2.33	2.01	3.20	3.85	32.98
83/84	0.90	1.60	2.43	1.03	2.23	2.08	3.53	4.26	5.34	4.64	3.08	3.13	34.24
84/85	2.75	4.29	2.24	2.92	2.09	2.66	1.58	3.11	5.22	3.98	3.55	3.26	37.66
85/86	4.91	4.47	4.28	2.89	3.00	2.56	2.72	3.24	3.90	3.34	4.21	5.59	45.11
86/87	6.51	5.91	5.35	4.38	2.66	2.46	2.11	3.28	3.07	1.55	3.43	2.92	43.61
87/88	4.67	4.67	4.04	2.57	3.19	3.88	4.39	5.87	4.16	5.71	5.66	5.86	54.66
88/89	4.67	4.62	3.15	2.15	1.26	1.73	1.78	3.53	5.32	5.50	4.99	4.75	43.45
89/90	5.10	5.19	4.31	3.22	1.99	2.21	2.47	4.03	3.30	3.51	2.21	1.74	39.27
90/91	2.51	3.00	1.61	2.96	1.84	1.61	1.91	2.85	3.78	3.24	3.44	2.13	30.89
91/92	2.09	2.63	1.78	1.32	0.58	0.18	1.41	2.36	2.32	2.79	2.73	2.84	23.02
92/93	3.69	3.63	2.26	1.45	1.00	0.82	1.26	2.38	2.78	2.24	1.57	3.19	26.29
93/94	3.96	3.24	3.29	2.46	1.47	1.30	1.87	2.97	2.29	2.07	2.07	2.57	29.55
94/95	4.13	3.52	2.53	2.01	1.40	1.39	2.49	4.85	4.43	3.66	4.19	3.77	38.36
95/96	4.26	3.76	2.31	1.63	1.16	0.72	1.83	0.55	1.97	2.30	1.48	3.08	25.06
Mean	3.55	3.45	2.80	2.02	1.45	1.40	2.09	3.04	3.36	3.09	2.91	3.14	32.30

9. Project Features

9.1 The Weir

For environmental considerations stipulated by the local authorities, the Weir had to be located downstream of the Manna-Keti fall. From the pool at the base of the fall the river runs flat for a short distance and is joined by a left bank tributary. Just downstream of the confluence is a narrow valley with fresh to moderately weathered bed rock suitable for the weir foundation. The river drops steeply thereafter for a few hundred metres on exposed bedrock.

As the project is run-of the river type minimal storage is required at the weir. The weir will be 20 metres long with a maximum height of 2 metres and an average height of a metre. Due to high flood flows the weir is designed as a concrete gravity structure. Dowels will be provided for added safety against sliding.

The Full Supply Level (FSL) of the pond is at El. 999.50 m.which will be approximately at 840 metres above Mean Sea Level. It is expected that the pond will be maintained about 0.3 metres below the FSL to prevent unnecessary spillage of water due to wave action.

The 100 year return flood peak at the weir site is estimated at 85 cumecs. Due to the steep bed slope of the river downstream of the weir and the availability of about 30 metres of width for flood flows the maximum flood height will not exceed 2 metres over the weir. Due to the short weir height and the comparatively high flood height the downstream slope of the weir was approximated to a slope of 1 to 1.

While the right bank of the river comprise of massive, unfractured bed rock fracture planes are noted at the center and the left bank. Inspection of the exposed bedrock downstream of the weir did not show any perceptive leakages. However grout holes will be drilled at one metre intervals at this section of the weir and pipes fitted, and tested and grouted after concreting of the weir. This will be a precautionary measure as any leakage will be minimal with a reservoir depth of 2 metres.

No siltation or sand deposits are observed at the weir location. The whole of the catchment area is a protected forest and no erosion or turbid waters have been observed even after heavy rains. However a by-pass pipe to eject silt and another to release the minimum flow requirements of the river will be provided through the weir.

Boulders in the pond close to the intake will be cleared.

It is expected that the pond will be a popular bathing spot for the Sri Pada Pilgrims. Structures is designed to blend with the natural features and to have the least impact on the environment.

9.2 Intake

The intake is a closed reinforced concrete conduit with a flow area 2 metres wide and 1 metre high and will slightly project in to the pond through the weir to minimize the entry of floating debris. There is trash bars spaced at 150 mm to prevent logs entering the channel and prevent bathers entering the conduit and provision for a stop-log gate.

The invert of the intake is at El 998.00. The intake will be designed for a maximum flow of 3 cumecs without the formation of a vortex to allow for uncertainities in the vortex formula.

9.3 Head Race Channel

The initial 20 metres of the channel from the intake is a closed conduit built in to the right abutment to prevent the entry of floods and to attenuate the flow through the conduit during high flood levels.

A side spillway 10 metres long is provided in the open channel built on rock immediately downstream of the closed conduit to spill the excess water entering at high flood levels.

A rubble masonry retaining wall is built to elevation 1002 to prevent flood waters entering the spill section over the right abutment. A vertical lift sliding gate with it's upper portion built in to the retaining wall will serve as the main control gate which will control the flow of water and also close the flow for maintenance and repairs. As the gate control wheel could be accessed at high flood levels it will also serve as an emergency closure gate during flood flows.

The headrace channel is of reinforced concrete, rectangular in section 2.0 metres wide and 1.2 metres high in the inside based on economic studies. The length of the channel is 280 metres and the bed slope 2.5 in 1000. The depth of flow at a flow of 2.7 cumecs is 0.9 metres allowing a freeboard of 300 mm. The channel is located in earth-cut, with crossings over minor streams. The channel is covered in most of it's length to prevent the ingress of trash and silt from the hill slope.

The channel will cross the Adam's Peak pilgrim path close to the forebay. The channel is a closed conduit at this section and the pilgrim path with the steps is reconstructed over this section.

9.4 Silt Settling Tank

Though no deposits of silt and sand have been observed in the pools in the river and the turbidity of the river water even after rains is of potable quality it was considered prudent to incorporate a silt settling tank in the channel to allow for any future change in land use and as the cost is relatively low. The silt settling tank is of a conventional design and will settle silt and sand to a particle size of 0.2 mm. A desilting gate will discharge the accumulated silt to a watercourse.

9.5 Forebay

The forebay is located on a hill slope of bedrock covered with a mantle of overburden less than a metre thick. The forebay is a reinforced concrete structure founded on the rock slope with the 1:4 rock slope incorporated into the tank volume to minimize rock excavation costs. The forebay will incorporate a spillway and a trashrack and is covered for security reasons.

The spillway has a discharge capacity of 3 cumecs with an efflux of 300 mm. and provision to divert the spill water to a nearby stream.

The trash rack has a clear spacing of 12 mm. and will have adequate area to allow a velocity of 0.6 m/sec with 30 percent of the area blocked at the minimum operating level.

The Maximum Operating Level of the Forebay is at El. 998.2 m. The Normal Operating Level will be El. 998.0 and the Minimum Operating Level El.997.0.

The Forebay should have adequate storage to allow sufficient time for manual operation and auto operation of the powerplant for changes in inflow by the operation of a level sensor and shutting off of the plant to prevent air entry to the penstock.

Following are the storage characteristics of the Forebay and the Channel:

i) Time for lowering of the Forebay Level by 150 mm
for a 10% reduction of inflow at maximum load - 60 seconds
ii) Time for lowering of the Forebay Level to MOL
for a 20% reduction of inflow at maximum load -360 seconds
iii) Time for lowering of the Forebay Level to MOL
with no inflow at intake and at maximum load -130 seconds
iv) Time for lowering of the Forebay Level to MOL
with no inflow at Forbay and at maximum load - 45 seconds

The above storage is adequate for operation by a waterlevel sensor set at 150 mm and a governor closing time of 20 seconds.

The Forebay would be the centre of operation for the headworks, and will have round the clock attendance for cleaning of trash rack and operation of the gate and security. Desilting is carried out on a pre-determined program.

9.6 Penstock

The penstock is 2400 metres long with a drop of 462 metres. The upper 1235 metres will a single pipe and the lower 1050 metres twin pipes. The thickness of the pipe is kept within 16 mm. to keep to low cost of pipe and to facilitate normal site welding.

The design of the penstock, anchors and piers is based on United States Bureau of Reclamation (USBR) Monographs and Technical Standards of Water Gate and Penstock Association of Japan.

The allowable design stresses is based on those successfully adopted in the specifications for major penstocks in Sri Lanka and based on material specifications and test reports on yield stress and ultimate stress provided by the penstock supplier.

Strict quality control of fabrication, welding and testing is ensured.

The Penstock Geometry and Pressures are given in Table 9.1 and Penstock Losses etc, in Table 9.2.

The penstock will have 33 anchors and piers at 12 metres. At a deep ravine between anchors A7 and A8 the piers will span 18 metres.

The single pipe penstock will reduce in outer diameter from 1.118 m. to 1.016 m. and thereafter to 0.914 m. and will bifurcates just upstream of Anchor A12 in to two pipes 0.813 m in diameter. The twin pipes will further reduce in diameter to 0.711 m. and 0.620 m and to 0.5 m. just before entry to powerhouse to suit the inlet valve diameter.

The penstock has sleeve bellow type expansion joints downstream of every anchor. The penstock is supported over the piers by saddle supports with a suitable sliding interface.

Typical pipe stresses in penstock pipe is given in Table 9.3 and typical forces in Penstock Anchors and piers are shown in Table 9.4

Anchor Blocks comprise of reinforced concrete structures with rubble masonry sections to provide additional mass required against sliding.

The penstock traverses transverse to the hill slope in most of it's middle section crossing streams. The high piers in these sections are designed as A- Frames which are economical in transmitting the dead load and sliding friction to the ground and the individual footings allow for sloped ground profile.

9.7 Powerhouse

The powerhouse is located on the right bank of Kuru Ganga at Adavikanda where the present public road from Eratna to Adavikanda ends. The powerhouse was located to ensure good foundation conditions and to be safe from floods of Kuru Ganga.

As the penstock runs parallel to the river the powerhouse is aligned normal to the river and the tailrace channel turned towards the river.

The turbine is set at the lowest level that meets the plant suppliers criteria for maximum tailwater level for operation during the maximum flood level in the river.

The Powerhouse building is a reinforced concrete structure 18 metres wide and 30 metres long. The main machine floor served by the overhead crane is only 10.5 metres wide.

The powerhouse has the machine bay, erection bay, the inlet valve bay, a control panel bay and a medium voltage room. There will be a office and record room adjacent to the control panel bay. A lobby, pantry, and a washroom will be located in a floor above the inlet valve bay.

The powerhouse superstructure is be a reinforced concrete frame with crane beams. Walls will be of blockwork, windows in aluminium and with a concrete roof.

A short open tailrace channel will convey the tail water to the river.

The switchyard is located close to the powerhouse and will have the two generator transformers and the service transformer and the connected switchgear. The terminal tower of the 33kv transmission line will be located at the end of the switchyard.

9.8 Powerhouse Electro-mechanical Equipment

The power house has two twin jet Pelton turbines coupled to two generators of 4.95 MW each. The Pelton turbines will be horizontal units operating at 750 rpm. The runner buckets are made with integrally cast stainless cast steel. The runner is directly coupled to the generator shaft. Jet deflectors are incorporated in the system to avoid excessive pressure rise in the penstock and proper speed regulation of the unit. Other equipment associated with the turbine are inlet valve, distributor, power nozzles and needles and governor and hydraulic systems.

Rated voltage of the generators is 6.3 kV. It conforms to DIN, VDE 0530, IEC 34 and ISO 8528-3 standards. Bearings of the generators are oil lubricated sleeve type and separate oil lubrication unit is used.

Two 6 MVA transformers are used to step up the generator voltage to grid voltage. These transformers are outdoor type. A 50 kVA transformer operating at 400 V is used for station supply.

A digital multifunction unit is used for synchronization. Following generator protections are incorporated.

- i) Over / Under Voltage
- ii) Over / Under frequency
- iii) Phase failure
- iv) Loss of mains, Rate of Change of Frequency
- v) Over current
- vi) Neutral Voltage Displacement

9.9 Transmission Line

A new transmission line with a length of 18 kilo meters has been constructed for the project. This new line is connected to Kosgama - Ratnapura 33 kV line. Pre-stressed concrete poles and SL type steel towers are used for the construction of the transmission line except Kuruwita town area where towers are used.. The route of the new line is same as the route taken by Existing Sri Pada line and Erathna 33 KV supply line. No fresh way leave clearance is required for transmission line.

10 PROJECT IMPLEMENTATION

Engineering consultancy services including engineering design, project management and supervision is entrusted to Ovara Private Limited.

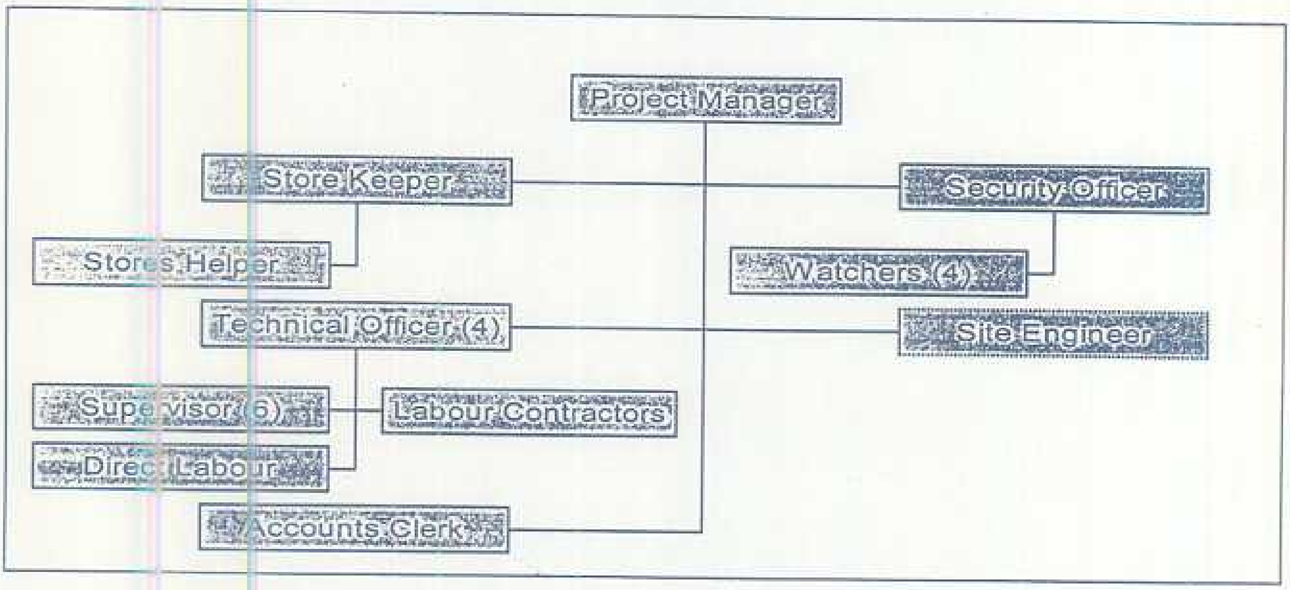
Erathna project site is a difficult one compared to other hydro sites. Transport of construction material and equipment in highly steep areas makes the construction work very difficult. Some equipment like compressors and concrete mixers need disassembling and in some occasions specials platforms to be made for movement of such equipment.

A group of sub-contractors are employed for civil construction work and payment to these contractors are on measure and pay basis. These contractors have prior experience in this type of projects.

Materials required for the project is directly procured by the site staff and a proper GRN system with BIN cards is maintained. Materials are issued on the basis of material requisition forms and cost allocations are done accordingly.

Motorable access to construction point plays a very important role as head carrying of materials involves a significant cost and implementation time. For example, head carrying of sand from stock yard at the office to the weir (3 kms) cost Rs.10,000 per M3 where as the cost of sand is only Rs.700/M3. The access road for the project is a 4 km long one with intermediate approaches. Inclusion of such an access road is a major comfort factor for project implementation.

Organization of the site staff is given in below.



10.1 Civil Work

3 labour contract groups are used for concrete, formwork and reinforcement fixing work and one group is used for masonry work in access road. Transport of materials from stockyards is done by direct crews.

10.2 Penstock

Three contractors were selected for penstock installation to three separate contractors. The contractors were identified after a suitable due diligence which included actual X-ray tests. The supervision and monitoring of actual laying and welding of the penstock has been undertaken by senior professional specialised in this field and a X-ray team.

10.3 Powerhouse

The design has been formulated in consultation and advise of the plant supplier. The construction has been carried out by a competent and recognized sub-contractor with experience in handling work of this nature.

10.4 Installation and Commissioning

The installation and commissioning of the plant has been carried out by the commissioning engineers of the supplier. Two engineers absorbed to the project company have engaged in co-ordination work and commissioning engineers have been assisted by local electricians and technicians.

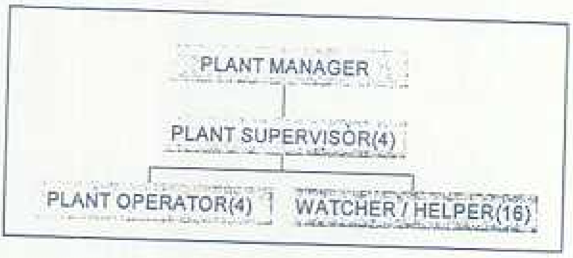
10.5 Transmission line

The transmission line is 18 km log. All materials have been purchased from the CEB. The construction tender was awarded to two contractors and construction was carried out under the supervision of CEB.

11 Operation and Maintenance

11.1 The operation and maintenance proposal has been formulated with the experience gathered from the operation of similar plants for a period of time.

11.2 Administration



Director Plant Operations stationed in Colombo will be responsible for operation of the plant. Plant Manager will be the over all in charge of the plant. There will be a 12 hour shift of supervisors helpers and operators.

11.3 Operation and Maintenance Practices

The plant is a full automatic one and operator interface is minimum. Operation of the plant system is performed by a control unit with liquid crystal display monitor. The monitor has a integrated keyboard The control panel is connected to by a cable to the stored programmed controller. All the set values required to operate the generating unit and the adjustment of various parameters can be performed through the control panel.

Following operation and maintenance practices will be adopted.

Outside Operation

Item	Remarks
Controlling the intake gate.	To be carried out by weir and forebay helpers
Sludge removal in sedimentation tank	Carried out by weir/ forebay helper
Cleaning of trash racks	Carried out by weir / forebay helper
Cleaning of storm water drains	Carried out by helpers.
Inspection of Penstock line from	Soil erosion to be noted. Inspection is

powerhouse to forebay and channel from forebay to weir after a heavy rain.	carried out by plant manager.

Spare parts

Following set of spare parts will be maintained.

1. AVR
2. Seals gaskets and packing for turbines
3. Solenoid valves for governor units
4. Power factor controller
5. Seals for hydraulic cylinders
6. Set of trip cards.

Routine maintenance

Following maintenance activities will be carried out in predetermined periods.

1. Change of Hydraulic Oils
2. Change of bearing oils.

If there is a failure in the CEB side, power that can be generated from our plant cannot be fed to grid. Therefor monitoring of losses due to CEB failures and quantifying same is very important. If the failure is Loss of Mains immediate action to be initiated with CEB to determine where the failure is and make arrangements with CEB to take necessary action.

All aspects regarding spare parts, routine maintenance etc. will be in accordance with the proposals made by the plant supplier.

12. Cost Estimates

12.1 SUMMARY SHEET

Bill no.	Description	Total cost
1	Preliminaries	97,020,318
2	Access road	17,824,020
3	Weir and intake	7,256,328
4	Head race channel	11,460,568
5	Penstock	153,670,767
6	Forebay tank	6,909,117
7	Power house and tail race	397,939,753
	Total	**692,080,871**

12.2 Bill no. 01 - Preliminaries

Item no.	Description	Unit	Quantity	Rate	Amount (LKR)
1.1	**Preliminaries**				
1.1.1	Provision for labour accommodation, sanitory facilities etc. (11 huts of 20 x 15m)	m2	2400	950	2,280,000
1.1.2	Site clearing for facilities (stores , toilets etc)	m2	2430	40	97,200
1.1.3	Construction of facilities - stores, site office, toilets etc.	m2	3300	3,450	11,385,000
1.1.4	Reconstruction of 2km of approach road	sum	1	2,542,318	2,542,318
1.1.5	Cost of resettlement of 5 families affected	Sum	1	7,945,800	7,945,800
1.2	**Pre operational expenditure**	sum	1	27,900,000	27,900,000
1.3	**Project management and consulting fees**	sum	1	18,600,000	18,600,000
1.4	**Procurament of land**	sum	1	8,270,000	8,270,000
1.5	**Financing cost**	sum	1	18,000,000	18,000,000
	Total of preliminaries carried to summary				**97,020,318**

12.3 Bill no. 02 - Access Road

Item no.	Description	Unit	Quantity	Rate (LKR)	Amount (LKR)
2.1	**Earth works**				
2.1.1	Excavation for road trace by excavator	Hrs	6,032	1,225	7,389,200
2.1.2	Manual excavation for foundation in normal soil	m3	210	300	62,970
2.1.3	Manual excavation for foundation in hard soil	m3	10	450	4,365
2.1.4	Blasting of rock	m3	1,680	1,240	2,083,200
2.2	**Masonry work**				
2.2.1	R/R masonry work in retaining walls, side drains and culverts	m3	623	4,000	2,492,000
2.2.1.1	6" x 9" Rubble paving in road pavement	m2	3,180	850	2,703,000
2.2.2	Semi rough plaster in culvert head wallsand retaining wall tops	m2	118	270	31,968
2.2.3	Plaster finished with neat cement in culvert head walls and retaining wall tops	m2	65	285	18,383
2.3	**Concrete works**				
2.3.1	Grade 15 concrete in screeds 50mm thick	m2	311	350	108,955
2.3.2	Grade 25 concrete in culvert side drains and ret. wall structure	m3	164	7,542	1,234,625
2.3.3	Form work for concreting	m2	830	750	622,125
2.3.4	Reinforcement in culvert and ret.wall foundation structure	kg	4,148	70	290,332
2.3.5	Hume pipes 300mm dia	ft	104	325	33,800
2.3.6	Hume pipes 600mm dia	ft	84	625	52,500
2.3.7	Hume pipes 1020mm dia	ft	276	725	200,100
2.3.8	Hume pipes 1350mm dia	ft	96	975	93,600
2.3.9	Dewatering during construction of structure foundations	Item	1	8,750	8,750
2.3.10	Gaurd stone	nos.	8	840	6,720
2.3.11	Sand filling between hume pipes	m3	23	1,150	26,427
2.40	**Miscellaneous Work**				
2.4.1	Cost of replaced Boutique	item	1	145,000	145,000
2.4.2	Shifting of hermit's living room at Maha oya	item	1	216,000	216,000
	Total of Access road Carried to Summary				**17,824,020**

Contractor: S.A.S.P. perara

12.4 Bill no. 03 - Weir and Intake

Item no.	Description	Unit	Quantity	Rate (LKR)	Amount (LKR)
3.1	**Preliminaries**				
3.1.1	Clearing of site	m2	25	40	1,000
3.2	**Earth works**				
3.2.1	Excavation of soil for foundation	m3	36	350	12,600
3.2.2	Blasting of rock	m3	185	1,465	271,025
3.2.3	Removing of blasted rock boulders	m3	185	510	94,350
3.3	**Masonry works**				
3.3.1	R.R. Masonry in flood protection wall	m3	78	6,368	496,704
3.4	**Concrete work**				
3.4.1	Concrete in weir structure - grade 20	m3	193	27,796	5,375,746
3.4.2	Form work for structure	m3	319	1,240	395,808
3.4.3	Reinforcement in structure	m2	2,168	90	195,120
3.4.4	Water bars	m	19	1,525	28,975
3.5	**Supply and fixing of gate**	Sum	1	385,000	385,000
	Total of Weir & Intake carried to summary				**7,256,328**

12.5 Bill no. 04 - Headrace Channel

Item no.	Description	Unit	Quantity	Rate (LKR)	Amount (LKR)
4.1	**Preliminaries**				
4.1.1	Clearing of path	m2	1,536	40	61,440
4.2	**Earth works**				
4.2.1	Manual excavation of soil for foundation	m3	583	350	204,050
4.2.2	Excavation of soil by excavator	Hrs.	80	1,250	100,000
4.2.2	Blasting of rock	m3	80	1,465	117,200
4.2.3	Removing of blasted rock boulders	m3	80	510	40,800
4.2.4	Back Filling with compaction	m3	64	412	26,368
4.3	**Masonry works**				
4.3.1	R.R. Masonry	m3	83	5,859	486,297
4.4	**Concrete work**				
4.4.1	Screed concrete 50mm thick	m2	801	555	444,777
4.4.2	Grade 25 concrete in structure	m3	383	14,133	5,415,766
4.4.3	Form work for structure	m3	1,899	840	1,595,160
4.4.4	Reinforcement in structure	m2	29,163	70	2,041,410
4.4.5	Construction of 2 over passes	Item	1	762,600	762,600
4.4.6	Water bars	m	108	1,525	164,700
	Total of HRC carried to summary				**11,460,568**

12.6 Bill no. 05 - Penstock

Item no.	Description	Unit	Quantity	Rate (LKR)	Amount(LKR)
5.1	**Preliminaries**				
5.1.1	Clearing of penstock trace	m2	7,290	40	291,600
5.2	**Earth works**				
5.2.1	Excavation in soil for penstock anchors and supports by excavator	Hrs	740	1,225	906,500
5.2.2	Blasting of rock in penstock trace	m3	2,328	1,360	3,166,080
5.2.3	Clearing of blasted rock by excavator	Hrs	1,180	1,290	1,522,200
5.2.4	Manual excavation of normal soil for foundation	m3	1,192	350	417,200
5.2.5	Manual excavation of hard soil for foundation	m3	82	450	36,900
5.2.6	Manual removing of blasted rock boulders in foundation pits	m3	44	510	22,440
5.2.7	Back Filling around structures with compaction	m3	164	412	67,568
5.3	**Masonry works**				
5.3.1	R.R. Masonery	m3	1,585	5,089	8,066,065
5.4	**Concrete work**				
5.4.1	Screed concrete under foundations 50mm thick	m2	1,390	555	771,450
5.4.2	Grade 25 concrete in support structures	m3	603	12,297	7,415,091
5.4.3	Grade 20 concrete in anchors	m3	1,357	11,231	15,240,467
5.4.4	Form work for support structures	m2	2,527	990	2,501,730
5.4.5	Form work for anchors	m2	1,183	760	899,156
5.4.6	Reinforcement work in anchors and support structures	kg	54,329	80	4,346,320
5.5	**Steel work**				
5.5.1	Supply and installation of penstock pipes and expansion joints	Sum	1	108,000,000	108,000,000
	Total of Penstock Civil carried to summary				**153,670,767**

12.7 Bill no. 06 - Forebay Tank

Item no.	Description	Unit	Quantity	Rate (LKR)	Amount (LKR)
	Value of work done before increase of rates				
6.1	**Preliminaries**				
6.1.1	Clearing of site location	m2	135	40	5,400
6.2	**Earth works**				
6.2.1	Excavation of soil for foundation	m3	35	350	12,250
6.2.2	Blasting of rock	m3	210	1,145	240,450
6.2.3	Removing of blasted rock by excavator	Hrs	90	1,225	110,250
6.2.5	Scaling of loose rock	man days	32	300	9,600
6.3	**Masonry works**				
6.3.1	R.R. Masonery in spill way	m3	125	3,087	385,875
6.4	**Concrete work**				
6.4.1	Screed concrete	m2	126	450	56,700
6.4.2	Grade 25 concrete in structure	m3	324	7,523	2,437,452
6.4.3	Form work for structure	m2	866	840	727,440
6.4.4	Reinforcement in structure	kg	35,250	80	2,820,000
6.4.6	Water bar	m	68	1,525	103,700
	Total of Forebay Tank carried to summary				**6,909,117**

12.8 Bill no. 07 - Power House

Item no.	Description	Unit	Quantity	Rate (LKR)	Amount (LKR)
7.1	**Preliminaries**				
7.1.1	Clearing of site	m2	2,430	40	97,200
7.2	**Earth Works**				
7.2.1	Excavation for foundation in soil by	Hrs.	2,016	1,225	2,469,600
7.2.2	Blasting of rock	m3	88	900	79,200
7.2.3	Back filling	m3	1,350	412	556,200
7.3	**Masonry work**				
7.3.1	R/R masonry work	m3	42	3,087	129,654
7.3.2	Block work	m2	2,430	650	1,579,500
7.3.3	Floor tiling	m2	572	1,620	926,640
7.3.4	Plaster	m2	4,860	310	1,506,600
7.3.5	Painting	m2	5,640	50	282,000
7.3.6	Toilet accessories	sum	1	72,500	72,500
7.4	**Concrete works**				
7.4.1	Grde 15 concrete in screeds 50mm thick	m2	291	435	126,585
7.4.2	Grade 20 concrete	m3	17	7,133	121,261
7.4.3	Grade 30 concrete in fdns & structures	m3	2,024	8,312	16,823,488
7.4.4	Form work for concreting in foundation	m2	145	725	105,125
7.4.5	Form work for concrete ground to 1st	m2	2,765	1,100	3,041,500
7.4.6	Form work for concrete 1st to 2nd floor	m2	625	1,320	825,000
7.4.7	Form work for concrete 2nd floor to roof	m2	650	1,584	1,029,600
7.4.8	Reinforcement	kg	125,670	90	11,310,300
7.5	**Doors and window - Alluminium**	sum	1	3,335,000	3,335,000
7.6	**Tubines, alternators, transformers and related accessories**	Sum	1	300,000,000	300,000,000
7.7	**Construction of new transmission line**	Sum	1	52,000,000	52,000,000
7.8	**Staff quarters - 2 units**	sum	1	1,620,000	1,620,000
	Summary				**397,939,753**

Erathna Mini-Hydro Power Project

FINANCIAL DATA SUMMARY

No.Units Per Year	32.30Gwh
Unit Rate - First Year (Rs.)	=5.85
Rate Escalation	3.00%
Project Costs (Millions)	692,000,000
O & M + Insurance First Year (Millions)	9,000,000
O & M + Insurance escalation 3 - 7 Year	5%
O & M + Insurance escalation 8 - 16 Year	8%
Depreciation	10%
Taxation	
2 - 11 Yrs	0%
After 11.Yrs	30%
Interest Rate	15%

FINANCIAL EVALUATION

CONTENTS

Erathna Mini-Hydro Power Project

Schedule - 1

Projected Income Statement

Details	Annex	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
Revenue																	
Hydro Power Generation (Note - 1)																	
Average No.of Units Generation (kwh)		-	32,300	32,300	32,300	32,300	32,300	32,300	32,300	32,300	32,300	32,300	32,300	32,300	32,300	32,300	32,300
Unit Rate/Kwh - Rs.		-	5.85	6.03	6.21	6.39	6.58	6.79	6.99	7.19	7.41	7.63	7.86	8.10	8.34	8.59	8.85
Total Revenue		-	188,955,000	194,[illegible]3,650	200,462,380	206,476,230	212,670,517	219,050,633	225,622,155	232,390,818	239,362,541	246,543,417	253,939,719	261,557,911	269,404,649	277,485,798	285,813,391
Expenses																	
Operating & Maintenance (Note-2)		-	9,000,000	9,450,000	9,922,500	10,418,625	10,939,556	11,486,534	12,405,457	13,397,893	14,469,725	15,627,303	16,877,487	18,227,686	19,685,901	21,260,773	22,961,635
Finance Charges	3	-	63,000,000	63,000,000	54,000,000	45,000,000	36,000,000	27,000,000	18,000,000	9,000,000	-	-	-	-	-	-	-
Depreciation	1	-	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	-	-	-	-	-
Preliminaries Written-off	4	-	45,000,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Expenses		-	181,770,000	136,220,000	127,692,500	119,188,625	110,709,556	102,256,534	94,175,457	86,167,893	78,239,725	79,397,303	16,877,487	18,227,686	19,685,901	21,260,773	22,961,635
Net Profit Before Tax		-	7,185,000	58,403,650	72,769,880	87,287,605	101,960,961	116,794,099	131,446,695	146,222,923	161,122,816	167,146,114	237,062,232	243,330,225	249,718,748	256,226,015	262,849,757
Taxation	2	-	-	-	-	-	-	-	-	-	-	-	67,931,077	69,811,476	71,728,031	73,680,211	75,687,334
Net Profit After Tax		-	7,185,000	58,403,650	72,769,880	87,287,605	101,960,961	116,794,099	131,446,695	146,222,923	161,122,816	167,146,114	169,131,156	173,518,751	177,990,716	182,545,803	187,182,423
Net Profit C/F		-	7,185,000	65,588,650	138,358,510	225,646,115	327,607,076	444,401,174	575,847,869	722,070,792	883,193,608	1,050,339,722	1,219,470,878	1,392,989,629	1,570,980,345	1,753,526,148	1,940,708,571

Note - 1
Hydro Power Generation

Rate as per Aggreement Rs.	5.65
Special Incentive	15.00%

Floor Price not less than 90% of PPA price

Therefore 1st Year Rate 5.65 X 1.15 X 90% =5.85

Average Rate Escalation Assumed 3.00%

Note - 2
Operating & Maintenance
O & M is expected to increase by 5% from year 3 to year 7 and by 8% thereafter.

Erathna Mini-Hydro Power Project

Projected Balance Sheets (Rs.)

Schedule - 2

Details	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Preliminaries	46,000,000	-	-	-	-	-	-	-
Fixed Assets	-	582,230,000	518,460,000	454,690,000	390,920,000	327,150,000	263,380,000	199,610,000
Work in Progress	646,000,000	-	-	-	-	-	-	-
Net Current Assets/(Liabilities	(92,000,000)	24,955,000	87,128,650	163,668,510	254,726,115	360,457,076	481,021,174	616,237,869
Net Assets	600,000,000	607,185,000	605,588,650	618,358,510	645,646,115	687,607,076	744,401,174	815,847,869
Share Capital	180,000,000	180,000,000	180,000,000	180,000,000	180,000,000	180,000,000	180,000,000	180,000,000
Long Term Loans	420,000,000	420,000,000	360,000,000	300,000,000	240,000,000	180,000,000	120,000,000	60,000,000
Retained Profits	-	7,185,000	65,588,650	138,358,510	225,646,115	327,607,076	444,401,174	575,847,869
	600,000,000	607,185,000	605,588,650	618,358,510	645,646,115	687,607,076	744,401,174	815,847,869

Details	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
Preliminaries	-	-	-	-	-	-	-	-
Fixed Assets	135,840,000	72,070,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000
Work in Progress	-	-	-	-	-	-	-	-
Net Current Assets/(Liabilities	766,230,792	991,123,608	1,222,039,722	1,391,170,878	1,564,689,629	1,742,680,345	1,925,226,148	2,112,408,571
Net Assets	902,070,792	1,063,193,608	1,230,339,722	1,399,470,878	1,572,989,629	1,750,980,345	1,933,526,148	2,120,708,571
Share Capital	180,000,000	180,000,000	180,000,000	180,000,000	180,000,000	180,000,000	180,000,000	180,000,000
Long Term Loans	-	-	-	-	-	-	-	-
Retained Profits	722,070,792	883,193,608	1,050,339,722	1,219,470,878	1,392,989,629	1,570,980,345	1,753,526,148	1,940,708,571
	902,070,792	1,063,193,608	1,230,339,722	1,399,470,878	1,572,989,629	1,750,980,345	1,933,526,148	2,120,708,571

Erathna Mini-Hydro Power Project

Notes To The Balance Sheet

1. The Financing Structure proposed is as follows:

	%	Yr.1
Equity	26.01%	180,000,000
Long Term Debt	60.69%	420,000,000
Short Term Debt	13.29%	92,000,000
	100.00%	692,000,000

2. Net Current Assets/(Liabilities) Computation

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Current Assets								
Trade Debtors - 1 months	-	15,746,250	16,218,638	16,705,197	17,206,353	17,722,543	18,254,219	18,801,846
Others - 15% of OM	-	1,350,000	1,417,500	1,488,375	1,562,794	1,640,933	1,722,980	1,860,819
	-	17,096,250	17,636,138	18,193,572	18,769,146	19,363,477	19,977,200	20,662,664
Current Liabilities								
Payables - 20% of OM	-	1,800,000	1,890,000	1,984,500	2,083,725	2,187,911	2,297,307	2,481,091
Advances/Supplier Credit	92,000,000							
	92,000,000	1,800,000	1,890,000	1,984,500	2,083,725	2,187,911	2,297,307	2,481,091
	(92,000,000)	15,296,250	15,746,138	16,209,072	16,685,421	17,175,565	17,679,893	18,181,573
Cash Balances	-	9,658,750	71,382,513	147,459,438	238,040,694	343,281,510	463,341,282	598,056,296
Net Current Assets/(Liabiliti	(92,000,000)	24,955,000	87,128,650	163,668,510	254,726,115	360,457,076	481,021,174	616,237,869

	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
Current Assets								
Trade Debtors - 1 months	19,365,901	19,946,878	20,545,285	21,161,643	21,796,493	22,450,387	23,123,899	23,817,616
Others - 15% of OM	2,009,684	2,170,459	2,344,095	2,531,623	2,734,153	2,952,885	3,189,116	3,444,245
	21,375,585	22,117,337	22,889,380	23,693,266	24,530,645	25,403,272	26,313,015	27,261,861
Current Liabilities								
Payables - 20% of OM	2,679,579	2,893,945	3,125,461	3,375,497	3,645,537	3,937,180	4,252,155	4,592,327
Advances/Supplier Credit								
	2,679,579	2,893,945	3,125,461	3,375,497	3,645,537	3,937,180	4,252,155	4,592,327
	18,696,007	19,223,392	19,763,920	20,317,769	20,885,108	21,466,092	22,060,860	22,669,534
Cash Balances	747,534,786	971,900,216	1,202,275,803	1,370,853,109	1,543,804,520	1,721,214,253	1,903,165,288	2,089,739,037
Net Current Assets/(Liabiliti	766,230,792	991,123,608	1,222,039,722	1,391,170,878	1,564,689,629	1,742,680,345	1,925,226,148	2,112,408,571

Erathna Mini-Hydro Power Project

Projected Cashflow Statement (Rs.)

Schedule - 3

Details	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
Inflows																
Hydro Power Generation	-	188,955,000	194,623,650	200,462,380	206,476,230	212,670,517	219,050,633	225,622,152	232,390,816	239,362,541	246,543,417	253,939,719	261,557,911	269,404,648	277,486,788	285,811,391
Share Capital	180,000,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long Term Loans	420,000,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Inflows	600,000,000	188,955,000	194,623,650	200,462,380	206,476,230	212,670,517	219,050,633	225,622,152	232,390,816	239,362,541	246,543,417	253,939,719	261,557,911	269,404,648	277,486,788	285,811,391
Outflows																
Capital Investments	692,000,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating & Maintenance	-	9,000,000	9,450,000	9,922,500	10,418,625	10,939,556	11,486,534	12,405,457	13,397,893	14,469,725	15,627,303	16,877,487	18,227,686	19,685,901	21,260,773	22,961,635
Finance Charges	-	63,000,000	63,000,000	54,000,000	45,000,000	36,000,000	27,000,000	18,000,000	9,000,000	-	-	-	-	-	-	-
Loan Repayments	-	-	60,000,000	60,000,000	60,000,000	60,000,000	60,000,000	60,000,000	60,000,000	-	-	-	-	-	-	-
Taxation	-	-	-	-	-	-	-	-	-	-	-	67,931,077	69,811,475	71,728,031	73,680,211	75,667,334
Total Outflows	692,000,000	72,000,000	132,450,000	123,922,500	115,418,625	106,939,556	98,486,534	90,405,457	82,397,893	14,469,725	15,627,303	84,808,564	88,039,160	91,413,932	94,940,984	98,628,969
Net In/(Outflows)	(92,000,000)	116,955,000	62,173,650	76,539,880	91,057,605	105,730,961	120,564,099	135,216,695	149,992,923	224,892,816	230,916,114	169,131,156	173,518,751	177,990,716	182,545,803	187,182,423
Changes in Working Capital	92,000,000	(107,296,250)	(449,888)	(462,934)	(476,350)	(490,144)	(504,327)	(501,680)	(514,434)	(527,385)	(540,527)	(553,849)	(567,339)	(580,984)	(594,768)	(608,674)
Net In/(Decrease) in Cash & Equivalents	-	9,658,750	61,723,763	76,076,925	90,581,256	105,240,817	120,059,771	134,715,014	149,478,489	224,365,430	230,375,587	168,577,306	172,951,411	177,409,732	181,951,035	186,573,749
Cash & Cash Equivalents at Start of Year	-	-	9,658,750	71,382,513	147,459,438	238,040,694	343,281,510	463,341,282	598,056,296	747,534,786	971,900,216	1,202,275,803	1,370,853,109	1,543,804,520	1,721,214,253	1,903,165,288
Cash & Cash Equivalents at End of Year	-	9,658,750	71,382,513	147,459,438	238,040,694	343,281,510	463,341,282	598,056,296	747,534,786	971,900,216	1,202,275,803	1,370,853,109	1,543,804,520	1,721,214,253	1,903,165,288	2,089,735,037

Erathna Mini-Hydro Power Project

Schedule - 4

Financial Ratio Analysis

Details	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
Profitability																
NP Ratio (Before Tax)	-	3.80%	30.01%	36.30%	42.27%	47.94%	53.32%	58.26%	62.92%	67.31%	67.80%	93.35%	93.03%	92.69%	92.34%	91.97%
NP Ratio (After Tax)	-	3.80%	30.01%	36.30%	42.27%	47.94%	53.32%	58.26%	62.92%	67.31%	67.80%	66.60%	66.34%	66.07%	65.79%	65.49%
EPS (Rs)	-	0.40	3.24	4.04	4.85	5.66	6.49	7.30	8.12	8.95	9.29	9.40	9.64	9.89	10.14	10.40
IRR - Net Profits After Tax						-17.89%	-9.61%	-3.64%	0.77%	4.11%	6.55%	8.36%	9.76%	10.85%	11.72%	12.42%
IRR - Net Cashflows					#NUM!	-16.99%	-8.62%	-2.93%	1.42%	5.67%	8.53%	10.04%	11.23%	12.18%	12.93%	13.55%
Investment Ratios																
Return on Investment (ROI)	-	1.20%	10.82%	15.16%	20.78%	26.32%	38.93%	54.77%	81.23%	89.51%	92.86%	93.96%	96.40%	98.88%	101.41%	103.99%
Return on Equity (ROE)	-	3.99%	32.45%	40.43%	48.49%	56.64%	64.89%	73.03%	81.23%	89.51%	92.86%	93.96%	96.40%	98.88%	101.41%	103.99%
Net Assets Per Share (Rs.)	33.33	33.73	33.64	34.35	35.87	38.20	41.36	45.32	50.12	59.07	68.35	77.75	87.39	97.28	107.42	117.82
Gearing Ratio	233.33%	233.33%	200.00%	166.67%	133.33%	100.00%	66.67%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Liquidity																
Liquidity Ratio	-	14.86	47.10	83.47	123.25	165.75	210.38	249.37	286.95	343.48	392.00	413.14	430.21	443.62	453.76	460.99

Erathna Mini-Hydro Power Project

Fixed Assets & Depreciation (Rs.)

Annex - 1

Details	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
Capital Investment (Rs.000)																
Land	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000
Civilworks	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000	159,300,000
Plant & Machinary	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000	460,400,000
Finance Cost	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000	18,000,000
	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000	646,000,000
Depreciation @ 10% for 10 Yr	-	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	-	-	-	-	-
Depreciation C/F		63,770,000	127,540,000	191,310,000	255,080,000	318,850,000	382,620,000	446,390,000	510,160,000	573,930,000	637,700,000	637,700,000	637,700,000	637,700,000	637,700,000	637,700,000
WDV C/F	646,000,000	582,230,000	518,460,000	454,690,000	390,920,000	327,150,000	263,380,000	199,610,000	135,840,000	72,070,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000	8,300,000

Erathna Mini-Hydro Power Project

Taxation (Rs.)

Annex - 2

Details	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
Net Profot Before Tax	-	7,185,000	58,403,650	72,769,860	87,267,605	101,960,961	116,794,099	131,446,695	146,222,923	161,122,816	167,146,114	237,062,232	243,330,225	249,718,748	256,226,015	262,849,757
Disallowed Expenses																
Depreciation	-	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	63,770,000	-	-	-	-	-
Allowed Expenses																
Capital Allowances																
Civilworks @ 6.67%	-	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)
Plant & Machinary @ 50	-	(230,200,000)	(230,200,000)	-	-	-	-	-	-	-	-	-	-	-	-	-
Finance Cost	-	(18,000,000)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	(258,825,310)	(240,825,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)	(10,625,310)
Assessable Income/(Losses)	-	(187,870,310)	(118,851,660)	125,914,550	140,432,295	155,105,651	169,938,789	184,591,385	199,367,613	214,267,506	220,290,804	226,436,922	232,704,915	239,093,438	245,600,705	252,224,447
Trade Losses B/F/Set-Off	-	-	(187,870,310)	(306,521,970)	(180,607,421)	(40,175,125)	-	-	-	-	-	-	-	-	-	-
Net Asessable Income/(Loss)	-	(187,870,310)	(306,521,970)	(180,607,421)	(40,175,125)	114,930,526	169,938,789	184,591,385	199,367,613	214,267,506	220,290,804	226,436,922	232,704,915	239,093,438	245,600,705	252,224,447
Taxation Rate	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	30%	30%	30%	30%	30%
Taxation	-	-	-	-	-	-	-	-	-	-	-	67,931,077	69,811,475	71,728,031	73,680,211	75,667,334

Note :
The Tax Liability is assumed to arise from the first year of commercial operations at the rates prescribed above .

Erathna Mini-Hydro Power Project

Long Term Loans (Rs.)

Annex - 3

Details	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
Capital B/F	420,000,000	420,000,000	420,000,000	360,000,000	300,000,000	240,000,000	180,000,000	120,000,000	60,000,000	-	-	-	-	-	-	-
Interest Capitalised	18,000,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Repayment	-	-	(60,000,000)	(60,000,000)	(60,000,000)	(60,000,000)	(60,000,000)	(60,000,000)	(60,000,000)	-	-	-	-	-	-	-
C/F	420,000,000	420,000,000	360,000,000	300,000,000	240,000,000	180,000,000	120,000,000	60,000,000	-	-	-	-	-	-	-	-
Interest @ 15% P.M.	18,000,000	63,000,000	63,000,000	54,000,000	45,000,000	36,000,000	27,000,000	18,000,000	9,000,000	-	-	-	-	-	-	-

Annex - 4

Erathna Mini-Hydro Power Project

Capital Expenses	Rs.
Preliminaries	**46,000,000**
Land	**8,300,000**
Civilworks	
Engineering & Supervision	30,000,000
Weir and Intake	4,071,000
Head Race Channel	12,379,000
Forbay Tank	13,827,500
Penstock Supports	49,460,000
Power House	16,055,000
Others	33,507,500
	159,300,000
Plant & Machinary	
Penstock	100,380,000
Electromechnical	248,000,000
Transmission Line	35,000,000
Contingencies	58,785,500
Others	18,234,500
	460,400,000
Interest Capitalised	**18,000,000**
Total	**692,000,000**