PARTICIPATORY MICRO HYDRO-ELECTRIC POWER GENERATION[1]

Nishantha Edirisinghe, D Wijenayake, Oscar Amarasinghe & C M Wijayaratna [2]

INTRODUCTION

This paper examines a participatory and "market oriented" conservation effort in the upper Nilwala watershed. In this effort the International Irrigation Management Institute, IIMI, catalysed a process of mobilising resource users in the Bovitiya Dola sub-watershed to collaborate with: a) the Matara Integrated Rural Development Project (MIRDP), b) Integrated Technology Development Group (ITDG), a Non Governmental Organization (NGO) and c) Government agencies including the divisional and provincial secretariats to **develop a micro hydro-electric power plant and to establish a participatory conservation program in the catchment**. This joint venture was initiated by the Shared Control of Natural Resources, SCOR Project. SCOR is being implemented by IIMI and financed by the United States Agency for International Development, USAID.

SCOR is a participatory action-research project aimed at developing and testing a holistic interdisciplinary approach to **integrate environmental and conservation concerns with production goals.** The conservation strategy being tested in SCOR is different from traditional approaches. SCOR hypothesizes that a **package** of measures -- such as type of vegetation/crops, appropriate land and water saving and conservation practices, user rights to earn economic and other benefits from the (participatory) conservation of natural resources -- are more effective in protecting environmentally fragile lands in water basins and watersheds. The "package" should be selected in consultation with (or jointly with) the users and both conservation and production or other profitable uses of natural resources should be incorporated into the package. This means that the package provides adequate incentives -- such as profits, desired cash flow as well as non-monetory benefits -- to the user to motivate her/him to protect natural resources. Unless the "actors" are informed by the knowledge of potential impact and unless the profitable alternatives exist, environmentally inappropriate decisions will continue to be made.

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Watershed as the Basic Planning, Coordinating and Implementation Unit

The focus on watersheds as the basic planning, coordinating and implementation unit is an important feature of SCOR. The term watershed is defined as the area of land surface that drains water into a common point along a stream or river[3]. The rationale for using the watershed as the basic unit for integrated planning of (land and water) resources utilization is clear. The watershed is a physical entity geographically defined by an important natural resource, water; the ways in which the water in the upper parts of the watershed are used affect the ways in which it can be used downstream, and they affect the associated land resource.

Moreover, various parts of the watershed are physically and operationally linked in important ways, and the potential benefits from integrated use can be large.

In addition, the people in the different components of the watershed having access to different aspects of the natural resources base may be engaged in different economic activities, and may be of different social and/or cultural backgrounds. For example, people in the upper catchment areas may have very different environmental, economic and social conditions from those in associated irrigated commands and those in downstream areas of the irrigated areas. Thus, the personal and economic interests in the different areas do not necessarily coincide, introducing problems for planning and implementation. This implies that socioeconomic and institutional factors too influence the linkages between "upstream and downstream."

Thus, any conservation or environment management approach should consider those physical, socioeconomic, and institutional linkages that exist between upstream and downstream of a river basin/watershed, and between systems within watersheds (such as the variations within and between micro watersheds). It should also consider the role of users both in "production and conservation[4]." *In other words, sustainable agricultural development in the broad context of rural development in these areas requires a watershed-based integrated approach which not only optimizes the production, but also ensures the protection of the natural resources or production base with active participation of the users concerned.*

SCOR Project emphasizes an integrated participatory approach, and makes a substantial effort in linkage and coordination. Experience in the major irrigated commands in many countries has shown that the combination of the use of catalysts, sharing of information, and reasonable administrative and political support can bring divergent groups into successful cooperative activity. While the process will be more difficult in the context of the full watershed, *there is a reasonable probability of success, and the potential for major benefits.*

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[3] According to this definition there can be sub watersheds depending on the order of streams. Hence, the river basin can be considered as the highest order watershed.

[4] "Production" includes profitable agricultural, aquacultural and forestry use of natural resources, hydroelectric power generation etc.

THE PARTICIPATORY DEVELOPMENT PROCESS OF MICRO HYDRO-ELECTRIC POWER PROJECT

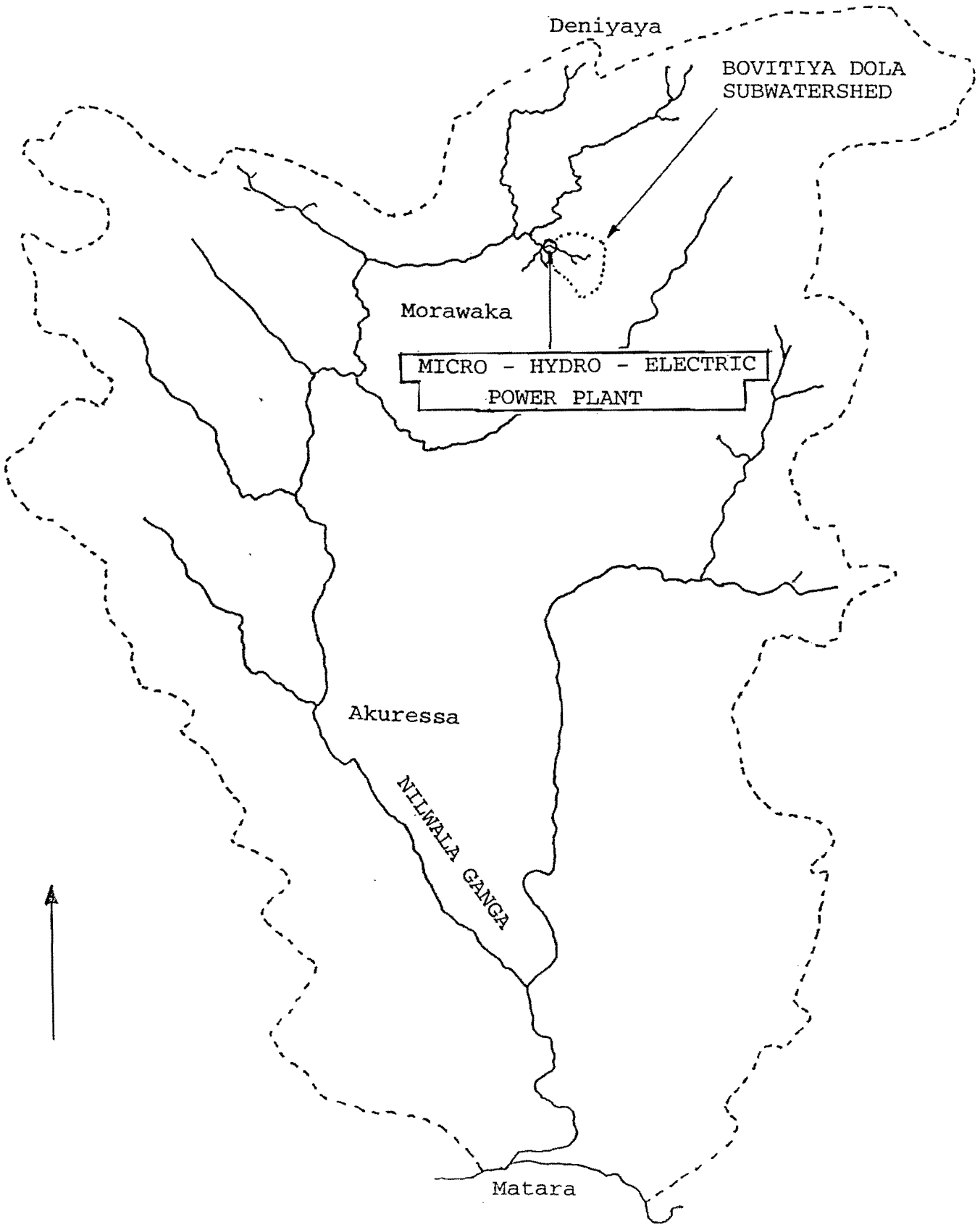
Illukpitiya villagers are the primary beneficiaries of the Micro Hydro-electric Power Project (MHPP). The village is located in the Bovitiya Dola sub watershed of the Nilwala Watershed/basin (Figure 1). The village consist of about 100 families. In January 1994, SCOR facilitated a participatory appraisal of natural resource use in the Bovitiya Dola Sub Watershed (BSW). This exercise, in addition to the preparation of land use maps, established a data base indicating the pre-project situation in regard to production, conservation (including apparent degree of soil erosion, slope categories etc and vegetation cover) incomes and profits, leadership/organizations and other socio-economic indicators. Table 1 shows the pre-project land use pattern in the sub watershed.

Table 1 Pre-Project Land Use Pattern - Bovitiya Dola Sub Watershed

	Land Use	Area (ha)	% Area
1.	Forest		
	high forest	18	10.3
	degraded forest	12	7.0
	fern & shrub etc.	14	8.1
2.	Tea	102	58.5
3.	Homestead	11	6.3
4.	Paddy	7	4.0
5.	Other	10	5.8
		174	100.0

Subsequently a participatory planning exercise was conducted and a resource management plan was formulated for the sub watershed. This was aimed at changing land and water use pattern to a more diversified resource use combining production (include. hydroelectric power generation) and conservation using appropriate technologies; novel shared control arrangements. This means that the villagers have "action-plans" that guide them along a path to the planned future from the current status of resource use. For example, planned change of land use indicated the following:

Figure I: Nilwala Ganga Watershed - Location of Micro Hydro - Electric Power Plant



- Adopted from Wijenayaka D., 1995.
- Scale 1 : 176,000

Forest cover	-	25% high forest
	-	05% well conserved "stream gardens" (horticultural crops & bamboo etc. with conservation measured)
Tea & Homegardens	-	70% (conservation farming)

During the planning sessions, villagers expressed deep concern for harnessing the Bovitiya Dola waterfall for generating electricity for both domestic consumption and small industries. Moreover, the need for protecting the catchment to ensure the sustainability of the hydroelectric power plant has been emphasized. It was noted that the village is located 2.5 km away from the main grid transmission and the estimated cost of supply is about Rs.3-4 million. Even the future possibility of grid connection remains bleak. An average family spends about Rs.145.00 per month for energy use; the main sources being kerosene and car batteries.

Because of the remote location and difficulties in accessibility villagers had less contacts with government departments and projects. Even though the villagers were aware of micro hydro electric power generation, they did not know how to obtain technical know-how, financial resources etc. There was no government agency directly responsible for micro hydro electric power generation.

Formation of User Organization

As decided during planning sessions, the villagers were organized into a cohesive group to develop and use the water fall/stream as the source of electricity **without having hostile effects on existing minor irrigation deliveries**. The IIMI catalyst facilitated this process. The organization, among other things, decided and designed action-plans for the following:

i. take collective measures to conserve and maintain the catchment;
ii. construct the hydro-electric power plant and supply electricity **directly** to 48 families;
iii. establish a "battery charging centre" and supply electricity **indirectly** to another 22 families;[5]
iv. invite the ITDG to provide mainly the technical assistance;
v. share a considerable portion of capital costs of construction in the form of (limited) capital and voluntary and organized labour;
vi. plan for an take over the responsibility for post-construction operation and maintenance of hydro electric power plant;
vi. undertake necessary post-project rehabilitation.

Roles and responsibilities of office bearers of the organizations have been defined and a nine-member committee was established as a day-to-day decision making body to expedite the construction process. Each member in this committee represented a small group of farmers.

[5] Anticipated power supply is limited to 5 KW and consumption will be confined to 5 pm to 7 am during week days and 2 pm to 7 pm over the weekends and holidays. The battery re-charging will be done by using the electricity generated during day time.

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"A Rights Issue"

Paddy farmers whose fields are located further downstream had two irrigation lines installed at the point where the weir is constructed. They feared that the construction of weir and the diversion of part of the Bovitiya Dola through the fore bay tank would reduce the flow of irrigation water to their fields. As a compromise, the members of the micro hydro electric power group, in a negotiation process, agreed to assign priority for irrigation and **fixed two irrigation lines three inches** below the level of the inflow to the turbine. After this arrangement was made in early 1994, no complaint has been made by the paddy farmers downstream concerning irrigation water indicating that the project has not given rise to negative externalities (implying zero external costs).

In order to maintain equity and also to optimize the limited power generated, the organization **decided to limit the supply to 100 W per household.**

Resources for the Construction of Micro Hydro Electric Power Plant

Members were requested to contribute Rs.1500 each in cash and supply construction material and labour equitably for construction. The organization borrowed Rs.11,000 at 2% annual interest rate from their apex farmer organization[6]. This organization expects to re cover the loan within two years after the construction of the power plant.

The proposal for hydro electric power development was submitted to Watershed Resources Management Team, WRMT[7]. The forest department official (who had participated in the design of catchment development efforts) commended that the users are motivated to conserve the forest. The representative of Agrarian Services Department cleared the project because it was clear that irrigation water rights have been protected. WRMT discussed the possibility of linking the proposal with the Matara Integrated Rural Development Project mainly to obtain funding for electro mechanical equipment. This proposal was well within the scope of MIRDP and the Director of that program, who is also a member of WRMT agreed to provide this balance funding.

In addition to the consultancy services, ITDG volunteered to supply a battery charger free of charge.

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[6] This apex organization, namely the Horagala Service Farmer Organization was formed as a result of SCOR intervention.

[7] WRMT is a working group established under the SCOR project to: guide and assist SCOR implementation, provide technical assistance, prepare workplans, develop close links with government programs, agencies and donor funded projects and help resolve conflicts. WRMT consists of IIMI technical experts, heads and experts from key government agencies, user representatives and divisional secretaries.

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Hydrological Considerations and the Design of Power Plant

IIMI watershed management co-ordinator, being an engineer, joined ITDG in providing technical assistance. He assisted the organization in the hydrological analysis.

The flow of the stream was computed measuring the stream flow during dry months of the year and studying the variations in the rest of the months. The "design flow" of the stream is 35 lit/sec. The older generation in the area reported that they had experienced a continuous flow (implying the perennial nature of the stream) before the destruction of forest in the catchment.

The location of diversion weir, inlet canals, forebay tank, penstock and power house were decided collectively by the users, ITDG and IIMI Watershed Management Co-ordinator. A low level spillway incorporated with a regulating device was also provided in the diversion weir close to left bank respecting users' opinion to protect the collapsing of right banks from. The team decided to provide silt exclusion devices at the diversion weir and forebay tank to protect turbine vanes from impacts of silt particles. Complying with the requirement laid down by the Central Environmental Authority of Sri Lanka and the Forest Department, user organization decided to build a stone terraced leader drain to discharge outflow of the turbine back to same stream to minimize damages to environment.

The main components of the design are shown in Figure 2.

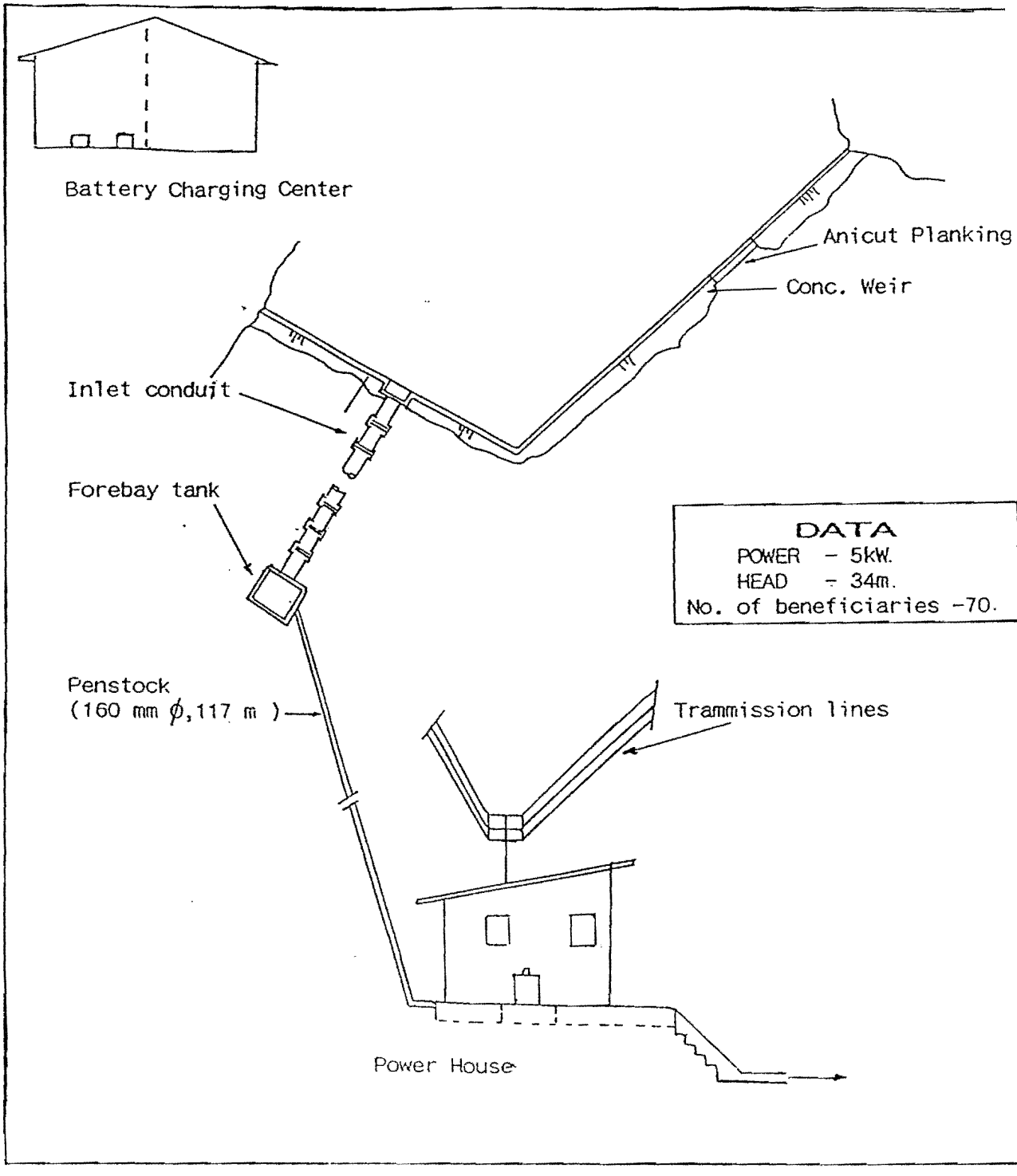
A PRELIMINARY ANALYSIS OF THE WORTH OF THE PROJECT

A preliminary analysis has been conducted to find out the worth of the project both from financial and economic view points.

Identification of Costs

Costs can be broadly divided into Direct and Indirect costs. Direct costs of the project include investment and operation and maintenance costs.

Figure 2: Bovitiyadola Micro Hydro - Electric Power Project



A. **Investment costs**

a. Cost of material for civil works: cost of material for civil work such as the construction of the weir, forebay tank and the power house;
b. Cost of electro mechanical equipment and connected services: the turbine and associated equipment which are installed at the power house;
c. Cost of transmission;
d. Cost of internal (house) wiring and connection from main line incurred by the beneficiaries;
e. Cost of labour: while for financial analysis of the project the labour payments in relation to voluntary group work were taken as zero, a shadow price has been assigned for the economic analysis. For house wiring, almost all the users had used paid skilled labour at the rate of Rs.60-70 per point. The aggregate amount was directly included in the analysis.
f. Contingencies and miscellaneous.

Table 2 provides a summary of these investment costs.

Table 2 Initial Investment Cost (Material)

Item	Cost (Rs.)
Civil construction	74,551.00
Electro-mechanical equipment	295,850.00
Transmission wires	143,586.00
Housing wiring	204,690.00
Connection from mains	32,050.00
Labour*	40,405.00*
Contingencies	15,000.00
Total	806,132.00

* For financial analysis only.

B. **Operation and Maintenance Costs**

a. *Cost of desilting channel bed*: It is assumed that the desilting will be done once in every two years by the organization through voluntary group work. It is estimated that 96 person days are required per operation. While for financial analysis, labour payments for desilting remain zero, for economic analysis, using the opportunity cost, the total labour per operation was estimated to be Rs.9,600 worth.

b. *Cost of operation*: A part time operator has been already appointed at a cost of Rs.500 per month. This person plucks tea also on a part time basis and uses his leisure time for power operations. Hence, the opportunity cost is considered as zero (for economic analysis).

c. *Replacement of bulbs*: Assuming that the life of a bulb is 1000 hours, cost of a bulb is Rs.25/- and the potential illuminating time is 1500 hours per year, the annual replacement cost would be Rs.7,200.

d. *Maintenance cost*: This is estimated at Rs.4000 per year.

Table 3 indicates the annual operation and maintenance costs.

Table 3 Annual Operation and Maintenance Costs

Item	Cost (Rs)
Desilting of channel bed	0*
Operating cost (operator)	6,000.00
Replacement cost of bulbs	7,200.00
Maintenance cost	4,000.00
Total	17,200.00

* For economic analysis the respective value is Rs.9,600 in every two years.

It should be noted that the time spent by ITDG, IIMI and MIRDP etc were not included in the analysis.

Indirect Costs

a. *Cost of battery charges and the building*: The market value of the charger (which was provided free of charge by the ITDG) is around Rs.15,000. The cost of construction of housing for the charger is Rs.10,000. Moreover, it is estimated that labour services worth Rs.5,000/- would be required for construction and installation purposes. The annual O&M cost is Rs.1,200.

b. *Externalaties on irrigation*: As explained earlier, priority is assigned to irrigation. Thus, it is assumed that the project has not given rise to negative externalities.

Identification of benefits

These can be divided into two broad categories: Direct and Indirect.

Direct benefits

a. *Direct Benefits from Conservation*: Pre-project land use pattern indicated the degree of degradation of catchment. Only 10% of the sub watershed was covered by high forest. Users were convinced that the sustainability of the MHPP would depend on the conservation of natural resources. In the participatory planning exercise they emphasized on the need for improving forest cover mainly to maintain stream flow at desired levels especially during the dry season and to reduce siltation. Since heavy soil erosion rate of the hydro-catchment necessitates frequent de-silting at the inlet structure and because higher sediment concentration in water reduces the life-span of the turbine, electricity consumers were motivated to take adequate action to reduce soil erosion, particularly in the tea lands. Beneficiaries decided to take action to prevent illicit felling of forest as well as to enrich the catchment in collaboration with the forest department.

The MHPP was inaugurated in mid December 1995, and by this time the organization had already completed re-forestation/ enrichment in 1.5 ha in the hydro-catchment. Table 4 indicates the plants established in different areas of the catchment and the current price of these species. Price is indicated only for timber species, other species such as Durian, Rambutan, Mango, Kitul, etc. can be even more valuable**.

**** Even though the organization has a plan to plant more to cover the entire area, these benefits are not included in the present analysis. A detailed analysis of (expected) benefits from conservation effort, including major indirect benefits, is in progress.**

Table 4 Plants established by electricity users organization (as of December 1994) and current price of species.

	Plant Species	Number	Timber/Value Rs/Tree
1.	Mahogany *(Swietenia macrophylla)*	852	15,000.00
2.	Hora *(Dipterocarpus ceylanicus)*	425	8,000.00
3.	*Accasia auriculiformis*	172	2,000.00
4.	Durian *(Durio zebethinus)*	48	
5.	Jak *(Artocarpus heterophyllus)*	182	20,000.00

6.	Arecanut *(Areca catechu)*	812	250.00
7.	Coffee *(Coffea arabica)*	40	
8.	Rambutan *(Nephelium lappaceum)*	74	
9.	Mango *(Mangifera indica)*	21	
10.	Keena *(Calophyllum spp)*	35	20,000.00
11.	Domba *(Calophyllum inophyllum)*	35	10,000.00
12.	Kitul *(Caryota urens)*	36	
13.	Bamboo	35	
14.	Other	52	

b. *Cost savings on Kerosene (used for lighting)*: Based on a SCOR field survey, the average Kerosene consumption is 8 lit./month per family. (4,550 liters by 48 beneficiary families). Therefore, annual savings would be Rs.40,950. However, as Kerosene is presently subsidized by Government, the true cost savings is considered to be Rs.48,093, in the economic analysis[8].

c. *Cost Savings on Batteries*: Twenty families in the village are using automobile batteries to operate televisions, cassette recorders, radios and sometimes for lighting neon bulbs (5 watts each). On the average, they re-charge batteries once in 3.5 weeks at a cost of Rs.34 per battery. However, after receiving hydroelectric power they may use batteries only during day time and therefore, the recharging frequency will be reduced to once in 7 weeks. The lifetime of such a battery may also changed from a present value of 2 years to about 3 years. While these direct cost savings will be used for financial analysis, the economic analysis will take into account potential cost savings in addition to actual cost savings. Costs of battery re-charging and replacement as well as savings, under different assumptions, are given in Table 5.

[8] The Govt. spends US$32.9 per barrel (159 liters) which means that the country incurs Rs.10.55 per liter. Including transport cost (Rs.0.20 per ton) the economic price of Kerosene at the sub-watershed is computed as Rs.10.57 per liter.

Table 5 Costs of battery recharging and replacement and savings after project

A No. of batteries	B Frequency of Recharging (weeks)	C No. of re-chargings per year	D Annual re-charging cost, Rs.	E Annual Replace-ment Cost, Rs.	F D + E Rs.	G Cost Savings Rs.
Present	3.5	14.86	10,102	25,000*	35,102	
= 20	7.0	7.43	5,051	16,666**	21,717	13,385
Potential	3.5	24,247	60,000	84,247*		
= 40	7.0	12,123	40,000	52,123**		31,124

Notes: Second row in each category indicates "after project" situation.

* assuming battery life of 2 yrs and that half of the batteries will be replaced each year.
** assuming battery life of 3 yrs and that 1/3 of the batteries will be replaced each year.

The Micro Hydroelectric Power Project generates only a limited amount of power. Also, the radius of electricity supply, without a costly transformer/converter, is also limited. Hence, only about 48 families will benefit directly from the MHPP while another 22 can use MHPP for re-charging batteries. A battery charging center has been established for this purpose. The center will charge only Rs.20 per battery for recharging, yielding a 14 rupee saving. Such savings are also included in the analysis.

In addition, field survey indicated that 28 families use torch batteries (dry cells) for radios and cassette recorders. Assuming that this consumption will be reduced by half after the project and at a price of Rs.18 per battery (and using the present monthly consumption level of 138 batteries), cost savings on torch batteries would be Rs.14,904.

Indirect benefits

a. *Production Incentives*: Electricity is an "incentive consumption good" which provides the potential consumers with incentives to increase production as it enables the consumer to utilize a wide range of durable electric goods such as televisions, cassette recorders, refrigerators, cookers, lamps, etc. Hence, MHPP will "induces" beneficiaries to increase production/incomes enabling them to purchase durable consumption goods. Economic analyses have been conducted at two levels: a) constant incomes and b) with 10% increase. The present opportunity cost of labour is considered as Rs.100 per day.

b. Another form of "production incentive" arising out of MWPP is the influence of electricity on **children's education** -- an investment on human capital. Although identified correctly, this influence cannot be measured accurately. **Hence this is not included in the analysis.**

c. *Reduce conflicts/complaints*: Informal sources indicate that the forest offences (or illegal logging) recorded in the forest range covering the sub watershed have declined. These will be monitored continuously. However, such benefits including the reduction in illegal logging activity, improved social harmony due to the formation of user organization for MHPP etc. **are not included** in the analysis.

Financial Analysis

Financial analysis, which considered only the direct costs and benefits of the MHPP used a discount rate of 6% as the opportunity cost of capital. This is the rate used by the National Planning Department for public investment activities. Financial analysis was conducted separately for two assumptions.

I. all potential battery users will have the opportunity of charging batteries (those who benefit from MHPP directly - 48 families - will use batteries during day time)

II. direct beneficiaries of MHPP will not use batteries.

Table 6 summarizes the results of financial analysis.

Table 6 Financial Analysis of the Micro Hydro-electric Power Project

Assumptions	Net Present Value (NPV) at 6%	B/C Ratio	Internal (Financial) Rate of Return (IRR) %
1	-207,088	0.79	2.4
2	3,677,448	1.37	11.0

Economic Analysis

Economic analysis included direct and secondary costs and benefits (except conservation benefits). It is assumed throughout the economic analysis that all the beneficiaries had used automobile batteries before the project. Taking into account the fact that electricity is an "incentive consumer good", the analysis is also carried out assuming a 10% increase in income. The analysis was conducted separately for the following assumptions:

I. all potential users will benefit from the battery re-charging as well;
II. all potential users will refrain from battery use after receiving electricity;
III. assumption I + 10% increase in income;
IV. assumption II + 10% increase in income.

The results of analysis are summarized in Table 7.

Table 7 Economic Analysis of the Micro Hydro-electric Power Project

Assumption	Net Present Value NPV, at 6%	B/C Ratio at 6%	Internal Rate of return,IRR,%
1	- 58,500	0.94	5.1
2	505,510	1.6	13.3
3	1,188,042	2.3	22.0
4	1,752,051	2.9	28.5

The economic analysis of the project indicates that it is very attractive, even without the conservation benefits. If these benefits or the impact of this "market oriented conservation" on the natural resources of the Bovitiya Dola watershed and the social benefits are included, the MHPP would have indicated a much higher return.

BOYITIYA DOLA MICRO WATERSHED PRODUCTION AND PROTECTION PROJECT AREA.

LAND USE APRIL 1994