THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

CEYLON ELECTRICITY BOARD

FEASIBILITY STUDY
ON
UPPER KOTMALE
HYDROELECTRIC POWER DEVELOPMENT PROJECT

FINAL REPORT

VOLUME 1

MAIN REPORT

AUGUST 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Democratic Socialist Republic of Sri Lanka, the Japanese Government has decided to conduct a feasibility study on the Upper Kotmale Hydroelectric Development Project and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Sri Lanka a survey team headed by Mr. Minoru Sayama, Chuo Kaihatsu Corporation, International, from November 1985 to January 1987.

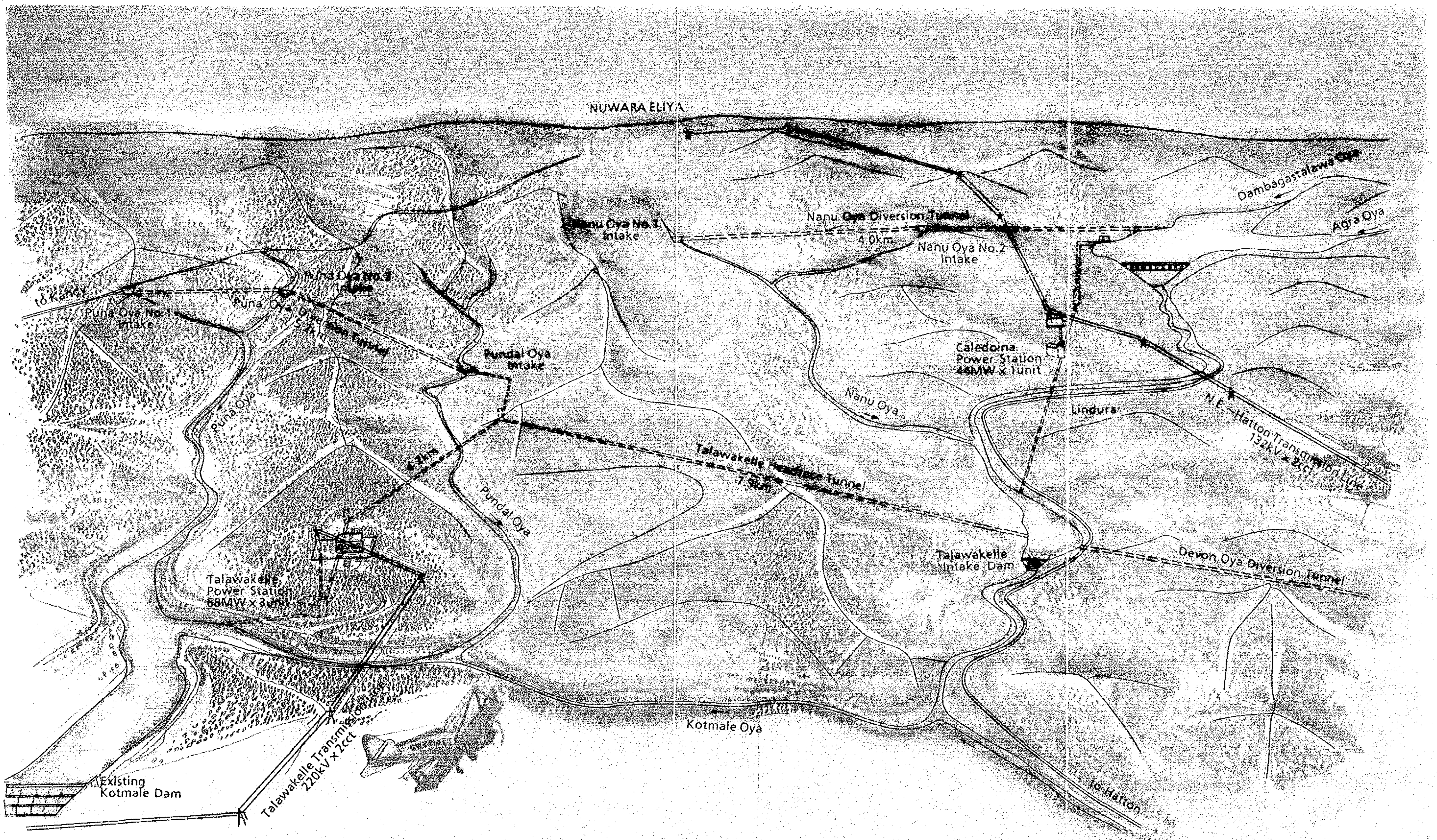
The team had discussions on the Project with the officials concerned of the Government of Sri Lanka and conducted a field survey in the Kotmale river basin. After the team returned to Japan, further studies were made and the present report has been prepared.

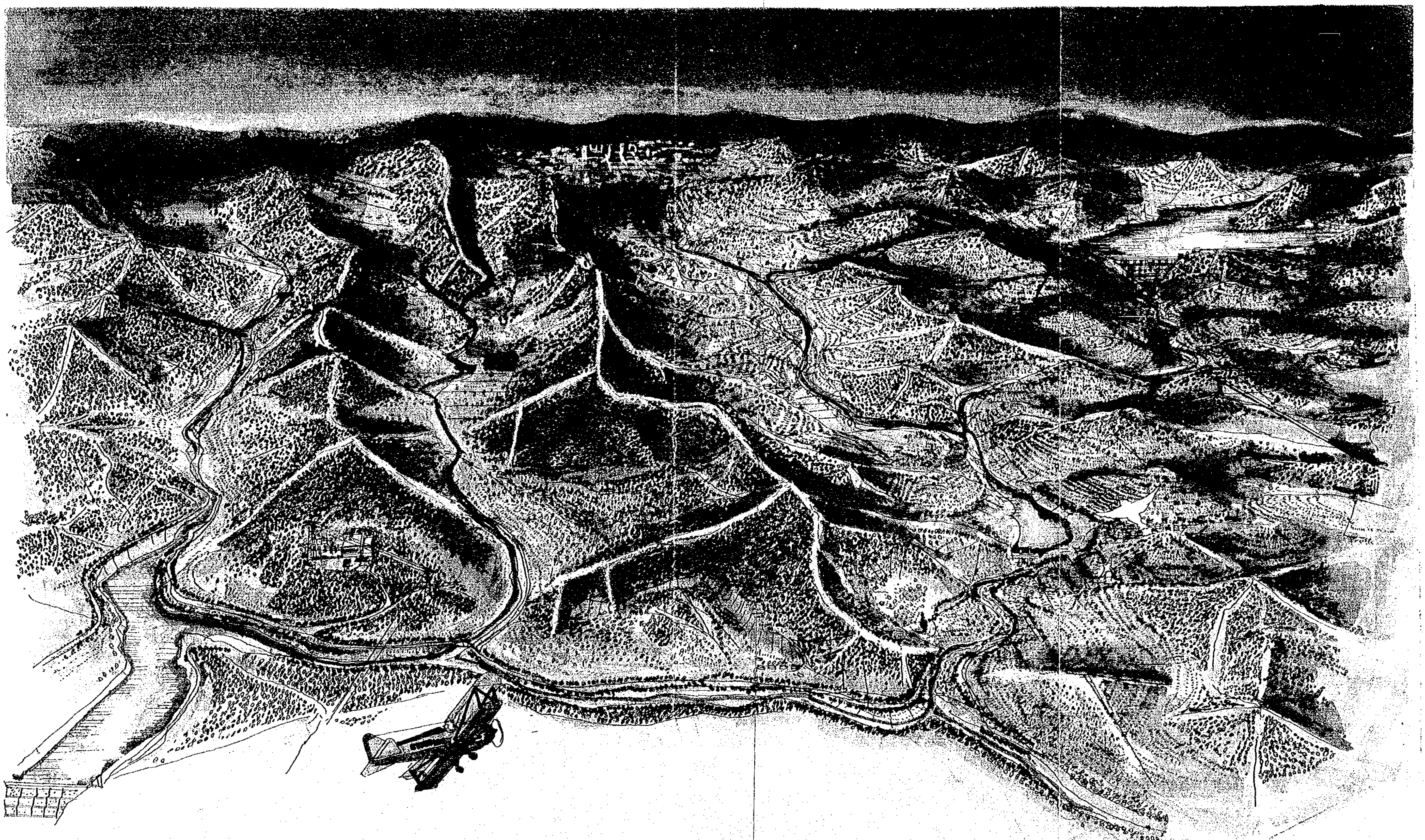
I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

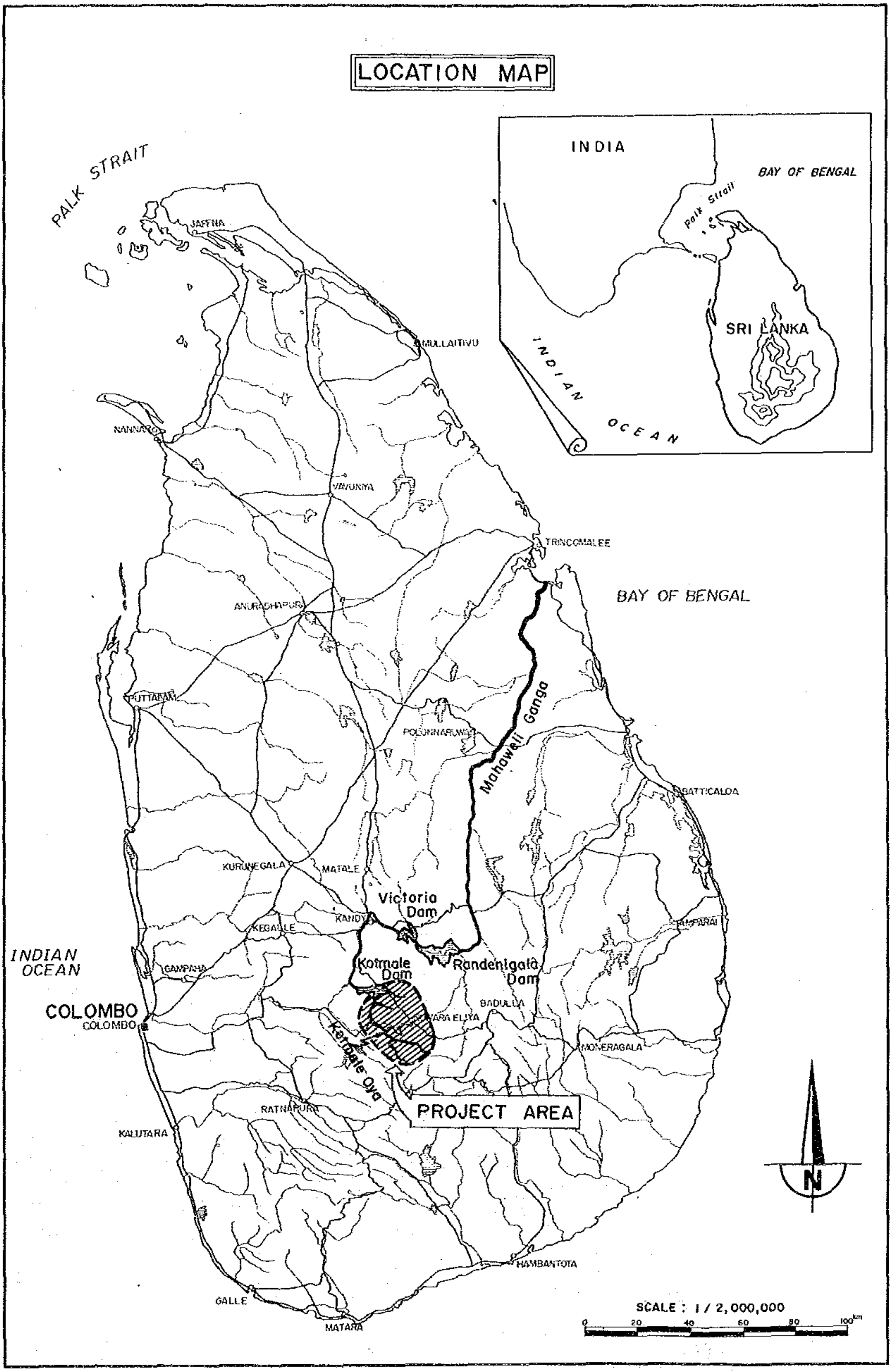
I wish to express my deep appreciation to the officials concerned of the Government of Sri Lanka for their close cooperation extended to the team.

August 1987

Keisuke Arita
President
Japan International
Cooperation Agency


NUWARA ELIYA
Dambagastalawa Oya
Agra Oya
Nanu Oya Diversion Tunnel
4.0km
Nanu Oya No.2
Intake
Intake
to Kandy
Puna Oya No.1
Intake
Pundal Oya
Intake
Puna Oya
Caledoina
Power Station
44MW x 1unit
Nanu Oya
Lindura
N.E.-Hatton Transmission Line
132kV x 2cct
Pundal Oya
Talawakelle
Intake Dam
Devon Oya Diversion Tunnel
Talawakelle
Power Station
68MW x 3unit
Kotmale Oya
to Hatton
Existing
Kotmale Dam
Talawakelle Transmission Line
220kV x 2cct




LOCATION MAP
INDIA
BAY OF BENGAL
Palk Strait
SRI LANKA
INDIAN OCEAN
PALK STRAIT
JAFFNA
MULLAITIVU
NANNARO
VAVUNIYA
TRINCOMALEE
BAY OF BENGAL
ANURADHAPURA
PUTTALAM
POLONNARUWA
Mahaweli Ganga
BATTICALOA
KURUNEGALA
MATALE
Victoria Dam
KANDY
KEGALLE
AMPARAI
INDIAN OCEAN
GAMPAHA
Kotmale Dam
Randenigala Dam
BADULLA
COLOMBO
COLOMBO
Kotmale Oya
MONERAGALA
PROJECT AREA
RATNAPURA
KALUTARA
N
HAMBANTOTA
GALLE
MATARA
SCALE : 1 / 2,000,000
0
20
40
60
80
100km

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

1. Economic Background

Sri Lanka achieved a steady average growth rate of 5.7% from 1977 to 1985 despite a worldwide recessionary trend and internal civil tensions during the same period. This growth is attributable to aggressive public investment policy on the part of the Government. However after 1985, economic growth has blunted and trade balance deficit rapidly increased due to a sudden drop in income from tourism resulting from intensified inner disturbances, and also due to a slump in international price of tea which is a major export item of the country. As a result, it is a task of great urgency for the Government to reduce consumption of imported energy and to develop export oriented industries.

2. Hydropower Development in Sri Lanka

Sri Lanka does not possess commercially developable coal, oil, or natural gas fuel resources, and fuel as an energy source has to be imported. However, the country possesses large potential for economically viable hydropower development, and the Government has aggressively pursued development of these resources in order to provide cheap energy for domestic and industrial consumption.

The current electrification rate in Sri Lanka is still low at 24% as of 1985. The development of remaining hydropower potential consequently warrants high priority. However, as 1,115MW out of 2,000MW of the nation's hydropower potential is scheduled to be developed by 1992, the following criteria must be given focus in implementing projects to tap the remaining potential:

(1) Maximum development of hydropower potential (effective utilization of water resources)

(2) High cost-effectiveness

(3) Design for peak power generation in conjunction with thermal generation

3. Role of Upper Kotmale Project within the Long Range Generation and Transmission Plan

With the recent completion of such large-scale hydropower projects as Victoria and Randenigala implemented under the Accelerated Mahaweli Development Project, current power generating capacity in Sri Lanka is 715MW of hydropower, 120MW of gas turbine and 80MW of diesels. A further 400MW of hydropower capacity is currently being constructed at Kotmale, Canyon II, Rantembe and Samanalawewa.

CEB conducts every year a 20 year power demand forecast and on this basis the Long Range Generation and Transmission Plan is formulated. Power demand forecast in 1986 prepared by CEB predicts power growth rates of 16% in 1987, 9% in 1988-2001, and 8% in 2002-2006.

However, due to the fact that even with the completion of ongoing projects, demand is expected to exceed supply after 1993 in response to anticipated economic growth, and the fact that favorable large-scale hydropower development sites are becoming fewer, introduction of 6 large-scale oil-fired units (total capacity 1,040MW) from 1993-2001 is planned in the Long Range Generation and Transmission Plan, 1986.

Nevertheless, because of the major importance of hydropower development to the national trade balance as an alternative to imported oil, the Upper Kotmale Project is included in the Long Range Generation Expansion Plan as a large-scale hydropower project to follow upon the Samanalawewa hydropower project, and commence operation by 1997 as suggested in the Alternate Plan in TABLE 2.2-8.

4. Optimum Development Plan

The Project area for Upper Kotmale hydropower development is situated in south central Sri Lanka and comprises the catchment of the Kotmale Oya, a tributary of the Mahaweli Ganga, upstream of the existing Kotmale dam. The Project area features favorable topographical, geological, hydrological, etc. conditions for hydropower development. The Project area has for a long time been developed with tea estates, and accordingly population density is relatively high and a labor force is readily available. Area road network is also developed, minimizing construction of new access roads for Project implementation.

The development approach to be adopted for the Project area must be such that it is both highly cost-effective, taking advantage of the abundant water resources (annual rainfall: 2,800mm) and steep river gradient of the area, and maximally develop the area's hydropower potential. On the basis of comparative study of numerous alternatives, it was determined that a two step development approach incorporating schemes at Caledonia and Talawakelle would be optimum. Said study was carried out with focus on the following criteria.

(1) The scale of reservoir at Caledonia at the upstream portion of the Project area is to be made as large as economically and technically feasible in order to maximally develop the area's potential as well as to obtain a larger firm energy.

(2) Maximum development of the area's hydropower potential is achieved also through diversion from the Nanu Oya on the right bank of the Kotmale Oya to Caledonia reservoir, diversion from Devon Oya on the left bank to Talawakelle pond, and by intake from the Pundal and Puna rivers on the right bank to the extent economically feasible.

(3) Both Caledonia and Talawakelle power stations are intended for peak generation. The optimum scale for these facilities was determined through comparative study of the various alternatives. On this basis, operating time during firm operation is 4.5hrs and the annual average is 9hrs.

(4) Planning for civil structures and selection of turbine type at Talawakelle power station was conducted on the premise that height of the existing Kotmale dam will be raised about 30m in the future.

Based on various comparative studies the optimum development proposal is determined as presented below:

	Caledonia	Talawakelle	Total
Catchment Area	235 km^2	363 km^2	--
Dam: Type Height Crest Length	Concrete Gravity 70 m 270 m	Concrete Gravity 20 m 102 m	-- -- --
Reservoir: Effective Capacity	 30 MCM	 2.0 MCM	--
Headrace: Main Branch	2,980 m 4,130 m	13,070 m 9,420 m	-- --
Tailrace	2,170 m	460 m	--
Power Station: Effective Head Maximum Turbine Discharge Maximum Output Annual Energy Firm Output Secondary Energy Plant Factor	 144 m 35 m^3/s 44 MW 135 GWh 76 GWh 59 GWh 35.0 %	 468 m 50 m^3/s 204 MW 674 GWh 331 GWh 343 GWh 37.7 %	 -- -- 248 MW 809 GWh 407 GWh 402 GWh 37.1 %
Construction Cost	Rs.4,160 million	Rs.5,640 million	Rs.9,800 million

5. Implementation Schedule

The subject hydropower development plan is characterized by high head, relatively small-scale reservoirs and long headrace waterways. Headrace tunnel construction is the critical pass in the overall construction period for the Project. The most efficient construction plan still results in a maximum tunnel segment of 7,400m.

The construction period for this longest tunnel is 5.5 years. The overall implementation schedule is accordingly formulated around the schedule for this work item. In order to ensure start-up of facilities by January 1997, the following tight construction schedule is necessary:

1. Internal procedure and approval: September 1987 - December 1987
2. Arrangement of loan package: January 1988 - May 1988

3. Preparation of detailed design for tendering, preparation of tender documents, tendering, tender evaluation: June 1988 - May 1991

4. Construction: June 1991 - December 1996

6. Project Economic Viability

Economic viability of the Project is high as evidenced by the indicators below:

Economic Internal Rate of Return (EIRR)

EIRR based on diesel as an alternative (alternative for secondary energy is the fuel for oil-fired steam) is 11.90%.

Financial Internal Rate of Return (FIRR)

Using present power tariffs (Rs.1.50/kWh) in Sri Lanka as a base, FIRR is 9.06%.

Energy cost

Annualized energy cost at a discount rate of 10% is Rs.1.24/kWh, comprising capital cost of Rs.1.22/kWh and O&M cost of Rs.0.02/kWh.

Reference

The above EIRR are based on costs for facilities, fuel and O&M for diesel which is provided by CEB. However, these values are considered to be slightly lower than international prices. For reference in this light, EIRR based on coal-fired facilities as an alternative (as was the case in evaluation of the Samanalawewa Hydropower Project for which construction was commenced in 1987) is 37.4%.

7. Intangible Benefit

Effect on Employment Opportunity Creation and Promotion of Linkage Industries

The overall cost required for implementation of the present Project is estimated at Rs.9,800 million. Of this, local currency portion which is to be spent in Sri Lanka amounts to Rs.4,338.2 million. Number of unskilled and skilled local labourers to be employed for construction works will average 2,100/day and 1,300/day, respectively. Thus, employment opportunity will be created and linkage industries in fields such as procurement, transportation, storage, etc. will be promoted by the development of the Project.

Development of Social Infrastructures

Through the implementation of the present project, the road network and power distribution lines will be developed for construction works. Social facilities, e.g. schools, dispensaries, community centers and recreation centers will also be constructed at construction camps and relocation areas. These facilities will be available to rural residents after Project works completion.

Promotion of New Industries

Creation of tourism industries can be considered by developing tourism facilities such as recreation facilities and accommodations in addition to the other social infrastructures previously discussed.

Development of inland fisheries utilizing the proposed Caledonia reservoir also can be considered through analysis and study on introduction of fishes appropriate for a reservoir at a high altitude of EL. 1,360m and with relatively low water temperature.

8. Social and Environmental Impact

The size of the reservoir and regulating pond envisaged for the Project are relatively small. The Caledonia reservoir has a compensation area of 3.35km2, and that for the Talawakelle regulating pond is 0.34km2. Inundated area comprises tea estate, river and road, and farmland and residences. Although compensation and resettlement will be required in the case of the affected population, no negative impact on the environment is foreseen. It is also concluded that no landslide threat of a scale posing danger to the area or its residents will result from ponding at the dams.

St. Clair, Devon, Ramboda and Puna falls are located at points where river discharge will be reduced as a result of the Project. Study was focused on power development that would allow for preservation of all falls in the area; however, findings showed that this would not be possible in the case of the most desirable development plan. As a result of consultations with CEB, it was decided to allow under the Project for one third of river average annual flow regulated as required at Devon Falls. No such maintenace flow is considered for St. Clair and other falls.

There is an existing power station (336kW, commenced operation in 1930) at Yoxford, 7km downstream from the proposed Talawakelle intake dam. Facilities are small scale and it is concluded that they can operate effectively with discharge from the residual catchment. There are some minor intakes for irrigation and domestic use on the Kotmale and its tributaries; however, no intake or water use facilites will be adversely affected by the Project.

Although no negative impact from the Project itself is foreseen on the environment, care must be taken during the construction period to avoid water and other environmental pollution.

CONCLUSIONS

1. The Project is of high economic viability. The structure sites for the hydropower development plan possess favorable natural conditions with regards to topography, geology and hydrology. Social and infrastructural conditions such as existing access road and labor availability are also good.

2. For both the Caledonia and Talawakelle schemes, headrace, penstock, power station, and tailrace facilities are to be underground. Geologic conditions in the Project area are generally good, and no structural problems for underground structures are expected. Neither are any technical problems envisaged.

3. The Project is characterized by high head in proportion to headrace length, good reservoir sites, and is suitable for peak power generation.

4. With introduction of large-scale oil fired units beginning in the 1990's, thermal generating capacity in Sri Lanka is to be 570MW in 1997 and 1,160MW in 2001. The subject Project is necessary as peak generating capacity for the efficient operation of the planned thermal units.

5. Given CEB's power demand forecast and the suggested alternate generating expansion plan in TABLE 2.2-8, it is necessary to target January 1997 for start-up of Project facilities operation.

6. Nine years is required to implement the Project including loan package arrangement, detailed design, tender document preparation, tendering, contract signing, preparatory works, main construction, and test operation.

RECOMMENDATIONS

1. The Project is economically advantageous in comparison to alternative energy sources. However, due to its large-scale nature, it is recommended that CEB promptly commence procedures to implement the Project in order that it be completed within the envisaged nine year period to allow start-up by January 1997.

2. Prior to implementation, the following study on preparations must be performed.

(1) Resettlement of an estimated 2,700 households is expected to be necessitated by ponding and establishment of work camps and construction yards. Careful considerations will have to be made in the resettlement of this population and provision with new employment.

(2) Construction of a total 40km of distribution line for construction power is necessary for Project implementation. It is considered that the potential contribution of such distribution line to improvement of quality of lifestyle for area residents following completion of the Project is great. Linkage of this construction use line with planning for electrification of the area should be adjusted with the relevant department prior to Project implementation.

3. Some falls in the area are subject to potential loss of scenic beauty due to decrease in discharge resulting from diversion under the Project. Concerned institutions must be persuaded of the high merits of this Project to the nation and the region, despite this potential loss.

4. In order to carry out accurate study at the detailed design stage, it is necessary that discharge observation be diligently continued to augment discharge data for tributaries of the Kotmale Oya.

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GLOSSARY AND ABBREVIATIONS

CEB	-	Ceylon Electricity Board
CECB	-	Central Engineering Consultancy Bureau
MOMD	-	Ministry of Mahaweli Development
MASL	-	Mahaweli Authority of Sri Lanka
ID	-	Irrigation Department
SD	-	Survey Department
GSD	-	Geological Survey Department
The Project	-	Upper Kotmale Hydroelectric Power Development Project
The Team	-	Feasibility Study Team for the Project
JICA	-	Japan International Cooperation Agency
ADB	-	Asian Development Bank
UNDP	-	United Nations Development Program
FAO	-	Food and Agriculture Organization
USAID	-	United States Agency for International Development
EEC	-	European Economic Community
IDA	-	International Development Association
US$	-	United States Döllars
Rs.	-	Sri Lankan Rupees
¥	-	Japanese Yen
GNP	-	Gross National Product
GDP	-	Gross Domestic Product
SDR	-	Special Drawing Rights
FC	-	Foreign Currency
LC	-	Local Currency
EIRR	-	Economic Internal Rate of Return
FIRR	-	Financial Internal Rate of Return
SCF	-	Standard Conversion Factor
CF	-	Conversion Factor
LRMC	-	Long-Run Marginal Costs
O&M	-	Operation and Maintenance
EL.	-	Elevation above MSL (Mean Sea Level)
WL.	-	Water Level above MSL
GL.	-	Ground Level

H.W.L.	-	Normal High Water Level
L.W.L.	-	Low Water Level
F.W.L.	-	Flood Water Level
mm	-	millimeter(s)
cm	-	centimeter(s)
m	-	meter(s)
km	-	kilometer
ha	-	hectare
km^2	-	square kilometer(s)
ft^2	-	Square feet
ℓ	-	liter
m^3	-	cubic meter
MCM	-	million cubic meter(s)
m^3/s	-	cubic meter per second
hr	-	hour
kg	-	kilogram
t (ton)	-	metric ton
%	-	percent
°C	-	degree centigrade
°	-	degree
Ø	-	diameter
BTU	-	British Thermal Unit
rpm	-	revolutions per minute
Hz	-	Hertz (cycles per second)
kcal	-	kilocalorie
V	-	volt
kV	-	kilovolt
A	-	ampere
kVA	-	kilovolt ampere
MVA	-	megavolt ampere
W	-	watt
kW	-	kilowatt
MW	-	megawatt
kWh	-	kilowatt hour
MWh	-	megawatt hour
GWh	-	gigawatt hour

CHAPTER I

INTRODUCTION

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INTRODUCTION

1.1 PROJECT HISTORY

Real economic growth in the Democratic Socialist Republic of Sri Lanka has continued at an average annual rate of 5.7% from 1977-85. Even in 1984 and 1985 which witnessed a worldwide recession as well as domestic social uncertainties, the growth rate reached 5.1% and 5.3%, respectively. A primary factor for this economic growth has been promotion of public investment through the Public Investment Programme, particularly concentrating on integrated development of the Mahaweli Basin. Power demand has grown apace with this economic development, increasing at a high annual average rate of 9.0% for eight years from 1977-85.

In 1984, power shortage was anticipated by further increases in power demand accompanying development thereafter, and preparation for implementation of Samanalawewa hydropower project in the Walawe Ganga basin was started successively to construction of large-scale hydropower projects at Kotmale, Victoria, Randenigala, etc. under the Accelerated Mahaweli Development Programme.

Supply deficit was, however, anticipated in the future supply and demand balance even with completion of these hydropower projects. As few untapped large scale hydropower potential sites remain, large-scale thermal power stations were accordingly planned to be introduced after 1993.

High priority was nevertheless placed on hydropower development in the Public Investment Programme because hydropower is an alternative to oil thermal which uses imported oil and thus contributes to improve the trade balance.

In view of the above background, Upper Kotmale hydropower development, the last large scale hydropower potential in the country, was targetted for urgent implementation in the Long Range Generation and Transmission Plan, 1984 with an envisioned operations start-up date of 1994. On 8 June 1984 the Government of Sri Lank made request to the Government of Japan for urgent implementation of a feasibility study on the Project.

In response to the request, the Government of Japan dispatched a preliminary survey mission headed by Mr T. Miura, the then Deputy Director, Mining & Industrial Planning and Survey Department, the Japan International Cooperation Agency (JICA) to Sri Lanka from February 18 to March 7, 1985 to confirm the contents of request and a contact mission from August 5 to 12 to make necessary arrangements for implementing the study. The Scope of Work for the feasibility study was drawn up and signed among the External Resources Department of the Ministry of Finance and Planning, Government of Sri Lanka, the Ceylon Electricity Board (CEB) and JICA. The feasibility study was commenced in November 1985 by a team dispatched by JICA and headed by Mr. M. Sayama.

1.2 Scope of Work

1.2.1 Study Objective

The objective of the Study is to formulate the technically and economically optimum hydropower development plan for the area upstream from the existing Kotmale dam on the Kotmale oya, a tributary of the Mahaweli ganga, and to prepare a feasibility study report.

1.2.2 Study Period and Schedule

The Study period is 24 months from November 1985 to October 1987 according to the original Scope of Work. On the basis of discussions between the Team and the Sri Lanka side, however, the Study period has been shortened by two months and the Final Report will be submitted in August 1987. The work period was divided on the basis of work content into four stages of implementation as outlined below.

Stage 1: November 1985 - March 1986 : field and home office works

- collection and analysis of basic data
- field reconnaissance
- aerophoto mapping, topo-mapping and river profiling
- study on the preliminary development plan
- preparation of a plan for Stage 3 field survey

Stage 2: April-July 1986 : home office work

- organization and analysis of collected data

- study on various alternative plans
- comparative design of main structures
- formulation of optimum development plan proposal
- preparation of Interim Report
- preparation of field survey schedule for Stage 3

Stage 3: August 1986 - January 1987 : field work

- presentation and discussion of Interim Report, and supplemental survey and data collection
- topographical survey instruction for 1/1000 scale map
- geological survey instruction by drilling and test pitting
- geological survey by seismic prospecting

Stage 4: January-August 1987 : field and home office works

- design of main structures
- estimation of construction cost
- technical evaluation
- economic and financial evaluation
- preparation of Draft Final and Final reports

1.2.3 Study Area

As stipulated in the S/W, the Study area covers the entire upstream portion of the Kotmale oya, a tributary of the Mahaweli Ganga above the existing Kotmale dam. Major tributaries of the main river, the Kotmale oya, (catchment: 554km^2 at the Kotmale dam site) are as follows:

MAJOR TRIBUTARIES IN THE STUDY AREA

River	Catchment (km^2)
1. Dambagastalawa	47.0
2. Agra	127.0
3. Nanu	83.0
4. Pundal	53.0
5. Puna	52.0
6. Devon	24.5

1.2.4 Participants of the Study

Members of the Feasibility Study team and Sri Lankan counterparts are presented below, while personnel contacted by the Team during the work in Sri Lanka are presented in ANNEX-1.

TABLE 1.2-1 FEASIBILITY STUDY TEAM

Assignment	Name	
Team Leader/Hydropower Development Planning	Minoru SAYAMA	Chuo Kaihatsu Corporation, International
Deputy Team Leader/Hydrologist	Keiji SASABE	"
Hydropower Engineer	Susumu FUNABIKI	"
Dam Engineer	Tsutomu KAMEYAMA	"
Economist	Masaaki NAGATA	Engineering Consultanting Firm's Association, Japan
Geologist	Tadashi OZEKI	Chuo Kaihatsu Corporation, International
"	Mutsumi MOTEGI	"
"	Masafumi NUKAZUKA	"
Geophysicist	Masami IWAYA	"
"	Kimio KAN	"
"	Masahiro SHIROTA	"
Topo & Geographic Survey Engineer	Katsuhiko YAMASHITA	Aero Asahi Corporation
Aerophoto Mapping Engineer	Kousuke TSURU	"
Facility Design Engineer	Noboru MURATA	Chuo Kaihatsu Corporation, International
"	Kazuo SAKAGAWA	"

TABLE 1.2-2 SRI LANKAN COUNTERPARTS

Assignment	Name	
Project Coordinator and Power Studies Engineer	T M Herat	Ceylon Electricity Board
Team Leader	U E Koswatta	Central Engineering Consultancy Bureau
Hydropower Engineer	U E Koswatta	"
"	G G Gamage	Ceylon Electricity Board
River Engineer (Hydrology)	L P G Silva	Central Engineering Consultancy Bureau
"	P Sooriyakumar	"
Dam Planning Engineer	H A L S Yapa	"
"	P M H G Rambanda	"
Planning Engineer/Field Studies and Cost Estimating	P C C Perera	Ceylon Electricity Board
Economist	H A L S Yapa	Central Engineering Consultancy Bureau
Geologist	H M Asoka Kumara	"
Drilling Engineer	B M A P Mapa	"
Seismic Prospecting Engineer	M A Wijeratne	"
Planning Engineer/Hydropower	W P S Fernando	"
"	J Nanthakumar	Ceylon Electricity Board
Civil Engineer/Surveys	I M Ranjith	Central Engineering Consultancy Bureau

Note: In addition, Counterparts from Survey Department, Irrigation Department, and Geological Survey Department participated in topo-survey and drilling.

CHAPTER II

BACKGROUND OF THE PROJECT

CHAPTER II

BACKGROUND OF THE PROJECT

2.1 National Background

2.1.1 General

Sri Lanka encompasses a total area of 65,610km^2 with a total population of 15,800,000 (as of 1985). Sri Lanka has one of the highest standards of education in South Asia, with primary school enrollment reaching almost 100% and an adult literacy rate of 85%. Life expectancy at birth for 1984 was estimated at 70 years.

Labor force composition as of the 1981 census (taken once every 10 years) consisted of a total potential work force of 4.119 million of which 1.876 million or about 45.5% are engaged in the agriculture, forestry and fishing sector, 16.8% are engaged in service, transportation and commercial activities and 10.7% in mining and industry. The numbers for unemployed and underemployed has greatly decreased compared to the 1970s; however the said rate in 1985 still reached 14%, 2% up from the previous year, due to depressed investment and stagnation in the tourism sector. It is urgently required to create employment opportunities for newcomers of 135,000 every year to the labor market.

Gross domestic product (GDP) in 1985 amounted to Rs109.570 billion in 1982 fixed prices (Rs149.415 billion at 1985 current prices). In terms of sector-wise contribution to the GDP, agriculture accounted for 27.5%, which although more than the 16.9% for mining and manufacture, was only roughly one-half the 55.6% for commercial, transportation and service sectors. This indicates low productivity of agriculture in proportion to the labor force in the agricultural sector. The per capita GNP in 1985 at the exchange rate at the end of that year was US$350.

In terms of labor population and sector-wise contribution ratios to the GNP, Sri Lanka is not a typical mono-culture agricultural society. Since before independence, the principal exports of the country have been tea, rubber and coconuts, and in 1985 these items still accounted for 48.8% (56.7% in 1984) of total exports. Although mining and manufacturing exports (including refined petroleum products) have been on the increase in recent years (38.7% in 1985 and 34.3% in 1984), the importance of tea, rubber and coconut exports is not anticipated to decline in the foreseeable future.

However, the fact that contribution to the GDP was 5.8% for tea, 1.5% for rubber and 3.7% for coconuts with 10.3% in total, as well as the fact that the three items accounted for only a little over 1/3 of total agriculture production (including other crops such as rice, etc. and fisheries) further underline the fact that Sri Lankan industries can not be defined as mono-cultural ones. In other words, although agriculture constitutes the principal mainstay of the Sri Lankan economic structure, tertiary industries such as the commercial sector, etc. are also extremely active.

2.1.2 Economic Trends

In 1977, the Government took steps to vitalize the economy under a liberalized economic policy. The real growth rate from 1971-77 had averaged only 2.9%/year; from 1977-85, however, the real annual growth rate reached an average of 5.7%. Even in 1984 and 1985, which witnessed a worldwide recession as well as domestic social uncertainties, the growth rates were 5.1% and 5.0%, respectively.

The primary contributions to this economic growth came from rice production, export-oriented industries, construction and service sectors, the growth of which is mainly attributable to implementation of new policies; namely, raises in government controlled prices, provision of incentives for non-traditional exports, reduction of import quotas, and government accelerated public investment. Public and private investments comprised 14.4% of the GDP in 1977; this figure had virtually doubled by 1983 (28.4%); and with Government efforts to curb public expenditures was still at 26.3% in 1984. As a result of vitalization of the economy, as mentioned before, the unemployment rate was reduced from 25% in 1977 to 14% in 1985.

Domestic savings however, were not sufficient to meet investments in the government and private sector and it was therefore necessary to borrow from foreign sources to fill up the investment-savings gap. The level of external financing grew from 3.6% of GNP in 1977 to 12.5% in 1983, and this, coupled with a slump in exports adversely affected the debt-service-ratio. In order to rectify financial deficits, the government adopted budgetary measures from 1984 to increase government revenues and to curb expenditures. As a result, foreign financing for investments dropped to 4.3% of GNP in 1984 hence returning to the 1970's level. However in 1985, the same ratio, again rose to 9.5% due to the fall in tea price and decrease in domestic savings.

Vitalization of the economy also resulted in high domestic inflation. The average annual increase in the consumers' price index rose from 5.7% for 1971-79 to 16.9% for 1978-83, as a result of excess demand due to increased public investments, devaluation of the rupee, sharp raises in import prices, particularly of oil, and policy induced increases in government controlled prices and wages. However, in 1984 and 1985 due to Government curbs on spending, tightening of financing conditions in the private sector and a drop in food prices and oil price accompanying increased agricultural production, inflation rapidly subsided in the last quarter of that year. In 1985, the inflation rate was 1.5%.

From 1978 to 1983 the balance of payments worsened. Subsequent to 1977, export earnings stagnated reflecting deterioration of the terms of trade. On the other hand, with increased import volume and rises in import prices, total import value from 1980 roughly doubled that for exports resulting in a deficit in current account amounting to 800 million SDR. In 1984, export earnings increased 45% due to a rise in the international price for tea and the development of some export products, most notably garments. This coupled with curbs on imports resulted in the trade deficits dropping to 400 million SDR. Furthermore, including net transfers and capital inflow, balance of payments registered a record surplus of 300 million SDR. The debt service ratio decreased from 21.9% in 1983 to 17.5%.

However in 1985, even though total import was at the average level for recent years, balance of payments returned to a deficit of 110 million SDR. This was due to a drop in the price of tea (a major export item in Sri Lanka) to almost one half that of the previous year, extreme decrease in income in the tourism sector, and increase in interest payments.

Economic growth in 1986 is assumed to have been slowed down with an actual growth rate at 4%, due to poor harvests in the agricultural sector (especially for rice and tea due to unfavorable weather), drop in investments, and decrease in income in the tourism sector, aggravated by intensification of internal disturbances. In almost all sectors beside oil refinery, the growth rates were below levels of 1984 and 1985. With a background as stated above, consumers prices which had been previously stable exhibited an increasing trend, especially with regards to foods. Prices in October increased 4.6% against the previous month and 7.2% in November. Terms of trade in 1986 were depressed, dropping 8% compared to the previous year. As a result of this coupled with decrease in income from the tourism sector, debt service ratio in 1986 resultingly worsened to 30.8% as compared with 22.3% in 1985.

Although stable development in the future greatly depends on international economic trends, improvement of government financial situations through tax reform, development of domestic industries, reduction of dependence on imported energy and internal stabilization should also be promoted.

2.1.3 Development Plans

Every year in May the Government of Sri Lanka draws up a revolving Five-year Public Investment Programme (PIP). During the final field survey period (February 1987), the PIP for 1986-90 was available for study. In this programme the economic policy of the last eight years is reviewed and summarized, and it was seen that despite difficult internal and external conditions, policy has showed remarkable resilience and made possible the attainment of a high growth rate. While following the present framework, the programme strongly emphasizes the need to take steps to rectify the various distortions which presently hinder economic reform.

The Government set a targeted annual average growth rate of 4.4% from 1986-90. Under a policy of high growth rate, the Government is endeavoring to strengthen the private sector in order that it may fulfill a more dynamic role in the economy. Participation of the public sector was restricted in investment projects where private management is more appropriate, and private investment is expected to increase with provision of various incentives. In particular, top priority is accorded development of non-traditional export items and to facilitate this, the National Export Development Strategy in which industries are identified for development (with accelerated development of required infrastructure thereof) was formulated seperately from the Five Year Public Investment Programme.

On the other hand, public investment is to be directed mainly at the development and acceleration of ongoing projects particularly with regards to social and economical infrastructures, and strengthening of the services sector; and thus, relative contribution of public investment to the GNP is to be reduced to some extent. The share of economic infrastructure in the total public investment is, however, increased to 21% in 1985 from 19% in 1978, and further targeted to 36% for the 5 years from 1986-90. Of this, 52% or Rs.8,920 million is schedule to be invested in electric energy projects, for which the government is expecting to cover the full amount from foreign assistance.

The high priority placed on electric power development projects by the Government reflects the forecasted rapid increase in energy demand accompanying industrialization. Present power supply capacity is estimated to be inadequate to fulfill power demand after 1990, and greatly increased oil imports, even though prices have recently decreased, for power generation and industrial activity will adversely affect the balance of payments. The Government of Sri Lanka therefore regards development of indigenous hydropower resources as an essential policy for energy conservation and economic development.

2.2 Electric Power Conditions

2.2.1 Administrative Organization

In Sri Lanka, electricity was first supplied in 1895 to Colombo for general electric lighting. In 1912, hydropower generation was begun in Blackpool, Nuwara Eliya. The government bought up private enterprises which had been producing electricity and formed the Department of Government Electricity Undertakings in 1927 which began efforts to develop electric energy. From 1955 the department also commenced its first rural electrification plan and since has continued to focus efforts in this area.

The Ceylon Electricity Board (CEB) was established on 1 November 1969 according to Gazette No.17 under the jurisdiction of the Ministry of Power and Energy. The CEB thereby became the sole agency undertaking power generation, transmission and distribution to the consumer.

A portion of electric supply (in recent years 25% of total electricity consumed) has been extended to rural areas through the local authorities. The same supply functions are however, now going to be gradually taken over by the Lanka Electricity Company (LECO) which was established in September, 1983. LECO is presently distributing electricity and conducting expansion and rehabilitation of distribution lines as duties assumed from nine local authorities around Colombo.

An organizational chart of CEB as of July 1985 is presented in FIG.2.2-1. CEB is managed by a General Manager under the supervision of a 8-member Board of Directors. CEB has the following departments besides managemental organization, and each department is controlled by an Additional General Manager or Deputy General Manager.

CEB employees totaled 13,192 in 1985.

- Commercial : Contracts & Supplies, Central Stores, Rural Electrification
- System Operation: Transmission Maintenance, System Control, Protection, Communication
- Generation Group : Mahaweli Complex, Laxapana Complex, Thermal Complex

- Region A : Northwest Division
  North Division
  Central Division
  Colombo Division
- Region B : East Division
  West Division
  South Division
- Transmission and Generation Projects
  : Transmission Construction, Construction Designs
- Transmission and Generation Planning : Transmission Planning, Generation Planning, Alternative Energy Development

2.2.2 Government Policy

As discussed earlier, large scale public investment has provided the impetus for economic development in recent years. In the electricity development sector, the government has agressively invested in construction of hydropower stations. The three hydropower stations, namely Victoria, Kotmale and Randenigala, implemented under the Accelerated Mahaweli Development Programme constituted the major portion of the said investment. Since 1978, the same programme has been the main recipient of government investment while budgets for investment in other sectors have been reduced.

However, with progress of the Accelerated Mahaweli Development Programme, the percentage of total public investment directed at the same dropped from 40% in 1980 to 24% in 1985 and is reduced to 16% in 1986. Thus investment in other projects has become possible; in the power development sector construction for Samanalawewa hydropower project was started in 1987 in the Walawe Ganga basin.

With the need to rectify the Government financial status which began to deteriorate in 1980, the Government placed curbs after 1984 on expenditures and focused on operation and maintenance of existing facilities rather than on new projects.

Under this policy, energy audits based on USAID technical cooperation and an energy conservation program in cooperation with UNDP have been implemented since 1984. The UNDP energy conservation program mainly consists of introduction of specific conservation measures and energy management training.

A program to reduce transmission loss from the present 15-20% to 10-12% in the 1990s is also being implemented based on the guidelines of CEB. In order to control energy demand, the Government reviewed and revised the electric fee system in March 1985 to establish a more realistic tariff system.

Rural electrification by construction of transmission lines and distribution system has been continuously promoted by the Government. With regard to the Transmission Project, Project VII and Project VIII are presently being undertaken, and the Rural Electrification Project is also being conducted with a fund provided by ADB.

2.2.3 Past Power Supply and Demand Status

Power demand in Sri Lanka has increased steadily over the past 20 years as indicated below.

TABLE 2.2-1 PAST POWER DEMAND

Period	Generated Energy (GWh)	Average Annual Growth Rate (%)	Maximum Demand (MW)	Average Annual Growth Rate (%)
1965	427.7		89	
1970	785.8	12.9	163	12.9
1975	1,078.8	6.5	219	6.1
1980	1,668.3	9.1	368.5	11.0
1985	2,464.1	8.1	514.9	6.9
Average		9.2		9.2

Historical change in peak power demand, generated and sold electric energy and energy consumption by sector from 1962 to 1985 is shown in FIG.2.2-2.

Major power consuming sectors in descending order of consumption volume are industry (including heavy, medium and small scale), local authorities, domestic, commercial and street lighting. In 1985, industry accounted for 41.3% of total power consumptions of 2,061GWh, local authorities for 24.3%, domestic use (including religious purpose) for 16.8% and commercial enterprises for 13.6%.

The power consumption growth rates over the previous year were highest for commercial enterprises (up 16.3%) and the hotel sector (up 18.9%). In spite of the Government's active persuit of power development, percentage of households electrified as of 1985 is still low at 24%. With a switch from wood, charcoal and oil to electricity as the energy source in the home, domestic power demand is forecasted to increase at a higher rate. Weekday and weekly average daily load curve taken from June 1985 are presented in FIG. 2.2-3.

Total energy consumption has increased at an average rate of 9% since 1965. As for the recent trend, growth rate was low due to insufficient power generating capacity, or in other words, supply constraints in 1980 and 1981. In 1983, a decline in the volume of water stored by the dams due to long-term drought, and increased unit cost of thermal generation due to increased oil prices resulted in a low growth rate for energy consumption. The growth rate for 1984 was also low despite improved energy conditions; however, this was due to control of power demand and implementation of an energy conservation policy.

Installed capacity and generated energy for hydropower and thermal power facilities since 1975 is indicated in TABLE 2.2-2 below. As clearly shown in the table, power demand rapidly increased from 1978. Hydropower development could not keep pace with the rapid demand increase, and thermal generation has accordingly increased yearly from 1978. In 1983, with drought as a contributing factor in reducing hydropower output, annual generated energy by thermal power amounted to 42.4% of total energy.

The power situation was, however, improved in 1984. In 1984, with the completion of Victoria hydropower station (210MW) hydropower capacity increased from 399MW to 609MW. In the same year, the Sapugaskanda diesel plant (80MW) was completed and accordingly with the stop of operation (1984-1989) of Kelanitissa Steam (50MW) and with obsolescence of Pettah and Chunuakam diesels (total 20MW), thermal capacity increased from 190MW to 200MW. The total capacity has thus increased to 809MW.

TABLE 2.2-2 INSTALLED CAPACITY AND GENERATED ENERGY FOR HYDROPOWER AND THERMAL POWER FACILITIES

Year	Installed Capacity (MW)			Annual Generated Energy (GWh)				
	Hydro	Thermal	Total	Hydro (1)	Thermal	Total (2)	Increase Rate (%)	(1)/(2) (%)
1975	291	70	361	1,078.4	0.1	1,078.5	6.6	100.0
1976	329	70	399	1,108.6	24.2	1,132.8	5.0	97.9
1977	329	70	399	1,214.4	2.1	1,216.5	7.4	99.8
1978	329	70	399	1,338.5	42.7	1,381.2	13.5	96.9
1979	329	70	399	1,461.2	64.3	1,525.5	10.4	95.8
1980	329	90	419	1,479.4	188.8	1,668.2	9.4	88.7
1981	369	130	499	1,571.2	300.1	1,871.3	12.2	84.0
1982	369	190	559	1,608.1	457.6	2,065.7	10.4	77.8
1983	399	190	589	1,217.2	897.4	2,114.6	2.4	57.6
1984	609	200	809	2,090.7	170.0	2,260.7	7.0	92.4
1985	609	200	809	2,394.6	69.4	2,464.0	8.9	97.2

Conversion of thermal power to hydropower also progressed and hydropower generated energy increased from 1,217GWh in 1983 to 2,091GWh in 1984 accounting for 92.4% of total energy. In 1984, due to the large share of generated output attributed to hydropower, fuel energy costs decreased from Rs.2.299 billion in 1983 to Rs.443 million.

These facts show the importance of hydropower development in Sri Lanka which is a non-oil producing country and presently suffers from a trade balance deficit. In Sri Lanka, energy consumption is rapidly increasing in conjunction with vigorous economic activity; however, due to commencement of Victoria hydropower plant operation, crude oil and petroleum products imports decreased for the first time against the previous year.

CRUDE AND PETROLEUM PRODUCTS IMPORTS

Import Item (1,000t)	1983	1984	1984/1983 Ratio
Crude Oil	1,492	1,733	1.16
Petroleum Products	487	129	0.26
Total	1,979	1,862	0.94

2.2.4 Existing Power Stations

Coal and petroleum resources which can be developed on a commercial base have not yet been found in Sri Lanka; and energy sources are imported crude oil, and domestic hydropower and fuel wood. Of these, hydropower is an especially valuable resource in Sri Lanka and hydropower potential which is economically and technically feasible for development is said to be 2,000MW. The Government has consequently continually pursued a policy of hydropower development.

Large scale hydropower development in Sri Lanka commenced with the Old Laxapana station commissioned in 1950 to generate 25MW. Hydropower development was consequently implemented in the Kehelgamu-Maskeliya basin. During the 1970's, Laxapana II, Wimala Surendra and Samanala (Polpitiya), etc. hydropower stations were constructed.

Under the first stage of Mahaweli development commenced in the late 1960's, a project was implemented for diversion of water from the Mahaweli Ganga to the Amban Ganga. The 38MW Ukuwela power station commissioned in 1976 utilizes this diverted discharge for power generation. The Ukuwela station is the first hydropower station in the Mahaweli basin.

Construction of the Polgolla headworks constituted the first step in the realization of UNDP/FAO Mahaweli Development Master Plan to be implemented over a 30 year period. In 1978, the Government formulated the Accelerated Programme to spur development of the Mahaweli Ganga. Under the Accelerated Programme, a series of large scale hydropower development schemes which include Kotmale, Victoria and Randenigala have been planned and almost completed.

Hydropower stations which are existing or under construction in Sri Lanka are as listed in tables 2.2-3 and 2.2-4 (refer to FIG.2.2-4).

TABLE 2.2-3 EXISTING HYDROPOWER STATIONS

Power Station	Year Operation Commenced	Installed Capacity (MW)	Maximum Turbine Discharge (m^3/s)	Rated Head (m)	Reservoir Eff. Storage Capacity (MCM)
1. Old Laxapana I	1950	25(8.33×3)	7.0	449	0.2
2. Old Laxapana II	1958	25(12.5×2)	7.0	"	0.2
3. Wimala Surendra	1965	50(25×2)	28.3	227	49.0
4. Samanala	1969	75(37.5×2)	34.0	259	0.09
5. New Laxapana	1974	100(50×2)	22.7	578	0.9
6. Ukuwela	1976	38(19×2)	56.6	78	1.2
7. Bowatenne	1981	40(40×1)	94.9	55	33.2
8. Canyon I	1983	30(30×1)	19.5	204	109.5
9. Victoria	1984	210(70×3)	140.0	190	688.0
10. Randenigala	1987	122(61×2)	180.0	78	797.0
Total	-	715			

Note: Minor stations i.e. Udawalawe (1968) 6MW and Inginiyagala (1954) 10MW are not included

TABLE 2.2-4 HYDROPOWER STATIONS UNDER CONSTRUCTION

Power Station	Target Year for Operation	Installed Capacity (MW)	Maximum Turbine Discharge (m^3/s)	Rated Head (m)	Reservoir Eff. Storage Capacity (MCM)
1. Kotmale I-III	1988	201(67×3)	76.0	202	152.0
2. Canyon II	1988	30(30×1)	19.5	204	109.5
3. Rantambe	1990	49(24.5×2)	180.0	32.7	16.6
4. Samanalawewa	1992	120(60×2)	42.0	345	254.0
Total	-	400			

Existing thermal power stations are as outlined in TABLE 2.2-5 (also refer to FIG.2.2-4).

TABLE 2.2-5 EXISTING THERMAL POWER STATIONS

Power Station	Year Operation Commenced	Installed Capacity (MW)	Remarks
1. Kelanitissa	1962/63	50	Oil Steam
2. Kelanitissa	1980	120 (20×6)	Gas Turbine
3. Sapugaskanda	1984	80 (20×4)	Diesel
Total		200	

Note: 1/ Kelanitissa oil steam is not included in the total since it has been non-operating from 1984. (It is planned for restart-up in 1989 and scheduled subsequent operation for 10 years).

: Pettah Diesel (1954) 6MW and Chunnakam Diesel (1954) 14MW are obsolete from 1984.

2.2.5 Potential Hydropower Projects

Hydropower potential in Sri Lanka is said to be equivalent to 2,000MW. Of this, 1,100MW are already developed or under construction as presented above. There are 10 existing stations with a total capacity of 715MW, and the 4 sites under construction have a total capacity of 400MW as presented above. Identified sites for future development including Upper Kotmale are shown in the following table (refer to FIG. 2.2-5).

TABLE 2.2-6 POTENTIAL HYDROPOWER PROJECTS

Stations	Capacity (MW)	Source
1. Upper Kotmale	248	Feasibility study
2. Broadlands	40	1986 Long Range Plan
3. Uma Oya	171	"
4. Kukule	180	1984 CEB Brochure
5. Jasmin	90	"
6. Haloluwa	30	"
7. Ratnapura	40	"
Total	799	"

2.2.6 Transmission and Dispatch System

The transmission network in Sri Lanka uses voltages of 220kV, 132kV and 66kV. As FIG.2.2-6 shows, the transmission network is centered around Colombo, the major demand area. The trunk line (220kV) runs east-west through the central part of the island connecting Colombo and Kotmale hydropower station, and is further extended to Victoria and Randenigala stations. Another 132kV trunk line traverses the island from south to north connecting Galle and Jaffna, passing Laxapana grid substation. Total length of transmission lines is 1,639km as of the end of 1985, of which 133km is 220kV, 1,167km is 132kV line, and 339km is 66kV line.

There are 31 grid substations as of the end of 1985, of which 2 are operated with a primary voltage of 220kV, 21 with 132kV and 8 substations with 66kV. Distribution lines consist of 33kV and 11kV, lengths as of 1985 are 7,909km and 2,245km, respectively.

TABLE 2.2-7 TRANSMISSION LINE LENGTH

UNIT: km

Voltage	1977	1981	1982	1983	1984	1985
220kV	-	-	-	-	-	133
132kV	897	1,013	1,013	1,013	1,132	1,167
66kV	317	339	339	339	339	339
Total	1,214	1,352	1,352	1,352	1,471	1,639

Source: Ceylon Electricity Board Annual Report 1982, 1983, Power for Prosperity, Statistical Digest 1984

Load dispatching in the Sri Lankan generation and transmission system is centralized at the CEB System Control Center located at Kolonnawa. At present, as the first phase of development a data acquisition, display and recording system have been installed whereby measurements such as output, amperage, voltage, and frequency indications of circuit breakers and isolators are automatically transmitted to the Master Control Center at Dematagode.

At present, the power stations and substations are under control by personnel on the spot. However, with expansion of control facilities in response to future requirements, it will be possible to send commands directly from the System Control Center.

The System Control Center performs the following functions: i) long term and short term operation planning, ii) system operation, iii) switching control, iv) disturbance monitoring and fault analysis, v) emergency operations, vi) operation procedures, vii) water management of hydro-thermal system, and viii) collection and analysis of data.

2.2.7 Future Supply and Demand Plan

CEB announced its Long Range Generation and Transmission Plan, 1986, in January 1987. This plan was prepared based on the following future demand increase projection. The high rate at 16.0% expected for 1987 is due to the recovery of lost loads in addition to the normal growth. The demand forecast is based on a past performance trending method, and considered appropriate by the Team's review as discussed in APPENDIX-III. Said forecast is as follows:

1987	16.0%
1988-2001	9.0%
2002-2006	8.0%

In this Long Range Plan, the Upper Kotmale Project was proposed to start operation in the year 2000. The subsequent study, however, revealed the high economic advantageousness of the Upper Kotmale Project and it was concluded that the Project is more beneficial compared to oil-thermal (2 units of 120MW and 4 units of 200MW) to be introduced from 1993-2000. Accordingly, an agreement was made between CEB and the Team to tentatively target operation commencement of the Project for January 1997.

The projected peak demand and facility alternate expansion plan up to the target year 2001 suggested for the study are presented in TABLE 2.2-8 and in FIG. 2.2-7. Installed capacity ratios for the same target year for hydro and thermal power are given in FIG. 2.2-8. Energy generation ratios assuming generated energy by hydro stations as firm + 1/4 secondary for the same target year for hydro and thermal are given in FIG. 2.2-8.

The <u>Long Range Generation and Transmission Plan</u> includes transmission expansion planning. In the latest plan (1986), a ten year plan is formulated based on a demand forecast for every grid substation. According to this plan, new construction of grid substations at 8 sites, and augmentation and rehabilitation at 23 grid substations including those under construction are proposed for the coming 10 years.

CEB is presently conducting gradual conversion of 66kV transmission system to 132kV system and in the 1986 long range plan, the construction of 132kV transmission line is proposed to be implemented for three years from 1987-89 on the existing Laxapan - Nuwara Eliya - Badulla (49+35=84km) 66kV route.

With regard to new construction of 132kV line, total 121km consisting of 40km from Balangoda to Embilipitiya via Samanalawewa hydro-station which is presently under construction, and 72km connecting Anuradhapura and Mannar are proposed. The 220kV double circuit line (operating as single circuit) is proposed to be constructed from Kotugoda via Habarana to Kilinochchi to avoid the overloading of the northern circuit. In the long range plan, reconducting of existing 132kV line is also proposed for an extension of 150km to be implemented in 1990-95.

TABLE 2.2-8 FUTURE ALTERNATE GENERATION EXPANSION PLAN

Year	Installed Capacity (MW)			Eff. Capacity (MW) 1/	Peak Demand (MW) 2/	Reserve Margin (%) 3/	Planned Projects (MW) 4/	Energy (GWh)		
	Hydro	Thermal	Total					Demand	Hydro 5/	Thermal 6/
1987	715	200	915	825	635	29.9	Randenigala:122	3,058	2,497	561
1988	946	"	1,146	1,056	692	52.6	Kotmale:67×3, Canyon II:30	3,333	2,825	508
1989	"	250	1,196	1,101	754	46.0	KPS oil steam:25×2	3,633	"	808
1990	995	"	1,245	1,150	822	39.9	Rantambe:49	3,960	3,017	943
1991	"	290	1,285	1,190	896	32.8	Diesel:20×2	4,316	"	1,299
1992	1,115	"	1,405	1,310	976	34.2	Samanalawewa:120	4,705	3,448	1,257
1993	"	410	1,525	1,335	1,064	25.5	Oil Steam I:120	5,128	"	1,680
1994	"	"	"	"	1,160	15.1		5,590	"	2,142
1995	"	530	1,645	1,455	1,265	15.0	Oil Steam II:120	6,093	"	2,645
1996	"	"	"	"	1,378	5.6		6,641	"	3,193
1997	1,363	"	1,893	1,703	1,502	13.4	Upper Kotmale:248	7,239	3,956	3,283
1998	"	610	1,973	"	1,637	4.0	Oil Steam III:200, KPS Gas:-120	7,890	"	3,934
1999	"	760	2,123	1,853	1,785	3.8	Oil Steam IV:200, KPS Steam:-50	8,600	"	4,644
2000	"	960	2,323	2,053	1,945	5.6	Oil Steam V:200	9,375	"	5,419
2001	"	1,160	2,523	2,253	2,121	6.2	Oil Steam VI:200	10,218	"	6,262

Note: 1/ Effective Capacity : The units of maximum capacity for both hydro and thermal are considered as non-effective
2/ Peak Demand : Peak demand at generation site (capacities also at generation site)
3/ Reserve Margin : (Eff. Capacity - Peak Demand)/(Peak Demand)
4/ Minus values indicate obsolescence beginning in the designated year.
5/ Generated Energy : (Firm) + (1/4 Secondary)
6/ Obtained by subtracting Hydro from Demand, the value is required thermal generation.

TABLE 2.2-9 GENERATION EXPANSION PLAN '86 (ORIGINAL)

Year	Installed Capacity (MW)			Eff. Capacity (MW) 1/	Peak Demand (MW) 2/	Reserve Margin (%) 3/	Planned Projects (MW) 4/	Energy (GWh)		
	Hydro	Thermal	Total					Demand	Hydro 5/	Thermal 6/
1987	715	200	915	825	635	29.9	Randenigala:122	3,058	2,497	561
1988	946	"	1,146	1,056	692	52.6	Kotmale:67×3, Canyon II:30	3,333	2,825	508
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1990	995	"	1,245	1,150	822	39.9	Rantambe:49	3,960	3,017	943
1991	"	290	1,285	1,190	896	32.8	Diesel:20×2	4,316	"	1,299
1992	1,115	"	1,405	1,310	976	34.2	Samanalawewa:120	4,705	3,448	1,257
1993	"	410	1,525	1,335	1,064	25.5	Oil Steam I:120	5,128	"	1,680
1994	"	"	"	"	1,160	15.1		5,590	"	2,142
1995	"	530	1,645	1,455	1,265	15.0	Oil Steam II:120	6,093	"	2,645
1996	"	"	"	"	1,378	5.6		6,641	"	3,193
1997	"	610	1,725	1,455	1,502	-3.1	Oil Steam III:200, KPS Gas:-120	7,239	3,448	3,791
1998	"	810	1,925	1,655	1,637	1.1	Oil Steam IV:200	7,890	"	4,442
1999	"	960	2,075	1,805	1,785	1.1	Oil Steam V:200, KPS Steam:-50	8,600	"	5,152
2000	1,363	960	2,323	2,053	1,945	5.6	Upper Kotmale:248	9,375	3,956	5,419
2001	"	1,160	2,523	2,253	2,121	6.2	Oil Steam VI:200	10,218	"	6,262

Note: 1/ Effective Capacity : The units of maximum capacity for both hydro and thermal are considered as non-effective

2/ Peak Demand : Peak demand at generation site (capacities also at generation site)

3/ Reserve Margin : (Eff. Capacity - Peak Demand)/(Peak Demand)

4/ Minus values indicate obsolescence beginning in the designated year.

5/ Generated Energy : (Firm) + (1/4 Secondary)

6/ Obtained by subtracting Hydro from Demand, the value is required thermal generation.

2.3 Need for the Project

As seen in the long range power supply and demand plan presented in TABLE 2.2-8, the Upper Kotmale project is necessary to achieve balance between power demand and supply in 1997. However, the Project is not only required for this reason, but also as it will function to produce peak power needed to ensure effective operation of the large-scale oil-fired plants to be introduced in the 1990's.

The current power supply system in Sri Lanka is primarily based on hydropower, with thermal-fired as a subordinate source. Hydropower is designed to respond to full load, while diesel and gas turbine plants function to provide one portion of peak load and augment hydropower during drought years. With the exception of the Kotmale project, hydro projects currently being implemented are designed for base load generation.

Power supply capacity by 1997, the target year for completion of the subject Project, is forcasted to be 1,363MW of hydropower and 530MW of thermal. Although this is still a hydropower-dominant, thermal-subordinate system, it can be seen in TABLE 2.2-8 that in 2001 thermal capacity rises sharply to 1,160MW versus 1,363MW for hydropower, and that in the early part of the 21st century Sri Lanka power supply will shift to thermal-dominant and hydropower-subordinant.

Under a thermal-dominant and hydropower-subordinant system, it is most cost-effective to utilize thermal and existing hydropower facilities with small reservoir capacity for base load and middle peak load generation, with reservoir and regulating pond type hydropower facilities with larger ponding capacity to respond to peak load. The facilities under the subject Project are accordingly designed for peak load generation.

As seen in TABLE 2.2-8, power supply-demand balance for 1987 and 1997 is as follows. Figures in parenthesis are values in the case where the Project is not implemented by 1997.

	1987	1997
(1) Installed Capacity	1987	1997
Hydropower	715	1,363MW (1,115)
Thermal	200	530MW (530)
Total	915MW	1,893MW (1,645)
(2) Effective Capacity		
Hydropower	645	1,293MW (1,045)
Thermal	180	410MW (410)
Total	825MW	1,703MW (1,455)
(3) Peak Demand	635MW	1,502MW
(4) Reserve Margin	29.9%	13.4% (-3.1%)

TABLE 2.2-8 indicates that reserve margin drops sharply after 1996. As a result, not only the subject Project, but also the oil-fired plants currently planned, merit careful consideration for implementation.

CHAPTER III

THE PROJECT AREA

CHAPTER III

THE PROJECT AREA

3.1 Location and Topography

3.1.1 Location and Access to the Site

The Project area is situated in the south central mountainous area of Sri Lanka and administratively belongs to Nuwara Eliya District. It covers the upstream catchment of the existing Kotmale reservoir on the Kotmale Oya, a tributary of the Mahaweli Ganga, and centers on 6°55' north latitude and 80°40' east longitude. The catchment is bounded on the southwest by the catchment of Mahaweli main course, on the southeast by the Walawe Ganga basin where the Samahalawewa hydro project is under construction and on the east by the catchment of the Uma Oya.

The district capital, Nuwara Eliya, is situated at the east end of the Project area at 6°58' north latitude and 80°46' east longitude, about 100km east of Colombo. With regard to access to the site from Colombo by vehicle, two major routes, one route via Kandy and the other via Hatton, are conceived as presented in FIG. 3.1-1.

Via Kandy:

			(via Gampola)	
Colombo	-------	Kandy	-------	Nuwara Eliya
	Route A1; 110km		Route A5; 75km	Total: 185km

Via Hatton:

			(via Hatton)	
Colombo	--------	Avissawella	--------	Nuwara Eliya
	Route A4; 55km		Route A7; 120km	Total: 175km

Railway is also available as shown in FIG. 3.1-1.

3.1.2 Prepared Topo-Map

Under the present feasibility study, the following maps have been prepared by aero-photo mapping and ground topo-survey. The area which each map covers is presented in FIG. 3.1-2.

TABLE 3.1-1 MAPS PREPARED THROUGH THE STUDY

Scale	Objective Area	No. of Sheets	Area (km2)	Method
1/10,000	Overall Project Area	17	407.0	Aerophoto mapping
1/5,000	Caledonia Dam and Reservoir	3	29.5	"
"	Caledonia P/S	1	2.55	"
"	Talawakelle Intake Dam	1	12.0	"
"	Talawakelle P/S	2	12.17	"
"	Nanu Oya Intake Route	1	11.25	"
"	Pundal Oya Intake	1	6.56	"
"	Puna Oya Intake Route	1	11.25	"
1/1,000	Caledonia Dam	2	0.53	Sectional Survey
"	Talawakelle Intake Dam	1	0.15	"
"	Talawakelle P/S	1	1.8	Plane Table survey

3.1.3 Topography

The Kotmale oya, the objective river under the Project, flows northwest from the confluence past Caledonia where it is joined by the Nanu oya. It then flows about 4km northwest where it turns abruptly to the northeast and proceeds into the Kotmale dam reservoir. River direction is clearly dominated by the geological structure; the northwest flow runs parallel to a fold axis while the abrupt turn to a northeast flow follows a fracture zone.

Elevations of mountains in the catchment area range from EL.2,524m at the top of Mt. Pidurutalagala, the highest peak in Sri Lanka, down to EL.703m, the retension water level of the existing Kotmale reservoir. The topography of the Project area consists of mountainous terrain dissected by the above mentioned large and small rivers such as the Kotmale, Nanu, Pundal, Puna, etc., forming long and narrow gorges.

Terrain is generally rugged, and slopes of river banks and a slope running northwest from the right bank of the Nanu are particularly steep with inclines ranging from 50-70°. Relatively gentle slopes are found below elevation of 1,500m, ridges upstream of Talawakelle form less sharp topography partly consisting of isolated hill formations.

These gentle slopes are mostly developed for tea plantation. Low flat lands at the bottom of the valley are less developed; small scale flat lands are found along the Kotmale Oya at its confluence with the Agra Dambagastalawa, Nanu and Pundal rivers.

As discussed early, the catchment area is largely covered by natural vegetation or tea estates, and wasteland is sparce. Directly upstream of the existing Kotmale dam, small areas of wasteland are present on both banks in the vicinity of landslide zones and where slopes are precipitous. Falls of scenic beauty are located at St. Clair, Devon, etc. on the Kotmale Oya and its tributaries.

3.2 Geology

3.2.1 General

Geological study and investigations conducted under the present Study include review and analysis of existing data, geomorphological study utilizing aerophotographs and topo-maps, surface gereological surveys in the objective area, seismic prospecting investigations, core drilling, Lugeon testing, laboratory rock testing, etc.

Seismic prospecting, drilling and laboratory rock testing were conducted as follows.

TABLE 3.2-1 SEISMIC PROSPECTING SURVEY AND CORE DRILLING QUANTITIES

Area	Seismic Prospecting Survey		Core Drilling	
	Number of Lines	Total Length (m)	Number of Holes	Total Depth (m)
Caledonia Dam	10	3,630	22	778.15
Caledonia P/S	4	2,985	2	220.0
Talawakelle Dam	2	400	6	155.87
Talawakelle P/S	7	5,470	4	623.55
Total	23	12,485	34	1,777.57

3.2.2 Physical Features

Sri Lanka extends in an oblong contour north-south with a land area of about 66,000km. The northern part of the island is generally flat terrain, while that to the south is well reliefed, consisting of peneplane deeply dissected by valleys. As seen in the following illustrations, the highest elevations on the island tend to be to the south rather than the center.

Research on the topography of Sri Lanka has been carried out over many years. According to such study, three marked topographical surfaces are identified. These are the Lowest Peneplane usually at elevation under 100ft (30m), occasionally occuring at 300-400ft, the Middle Peneplane at 2,500ft (762m) and the Highest Peneplane at 5,000-6,000ft (1,524-1829m), sometimes surpassing 7,000ft. A topographical profile composed by Cooray (1975) is presented on the next page.

The Project area is in a region of Highest Peneplane deeply dissected by rivers.

THE GEOLOGY OF CEYLON

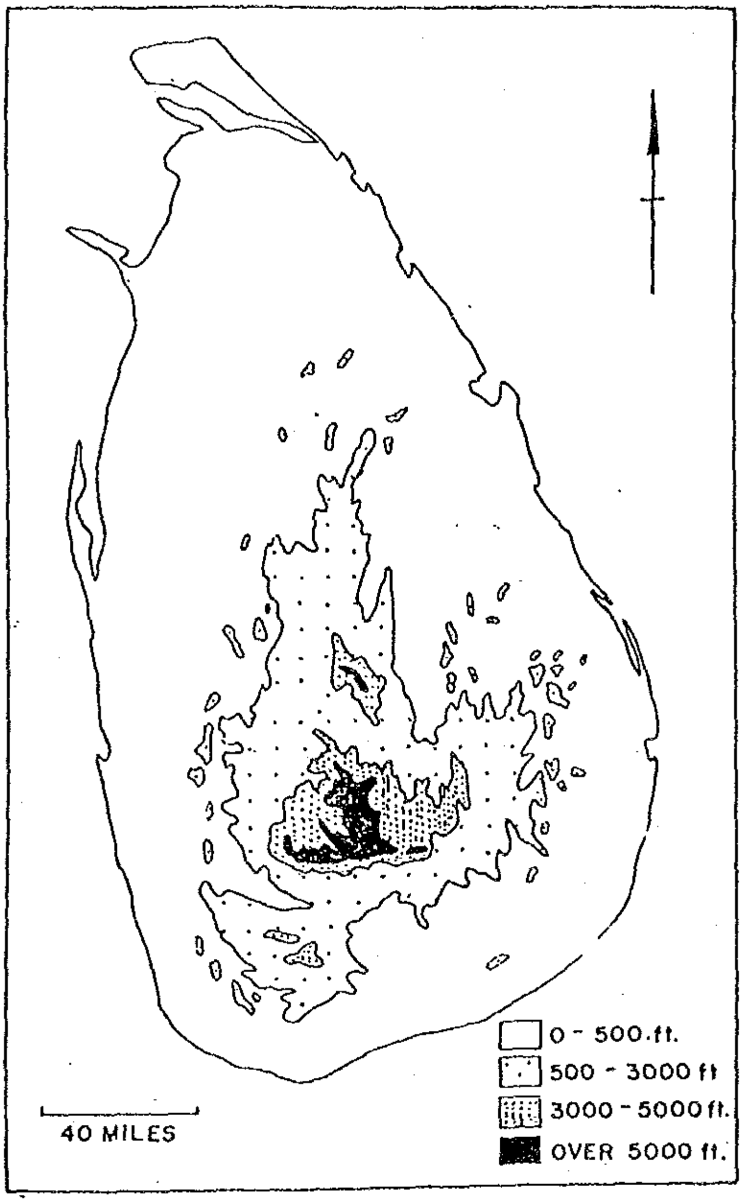


Fig. 17. Sketch map of the relief of Ceylon.
(The two small blank spaces in the south-west should have a close stipple, i.e., 3,000′—5,000′)

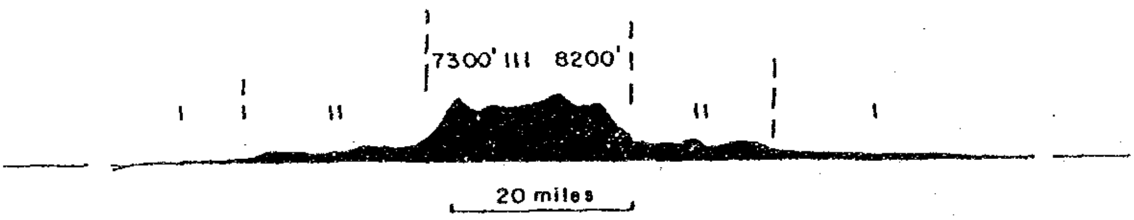


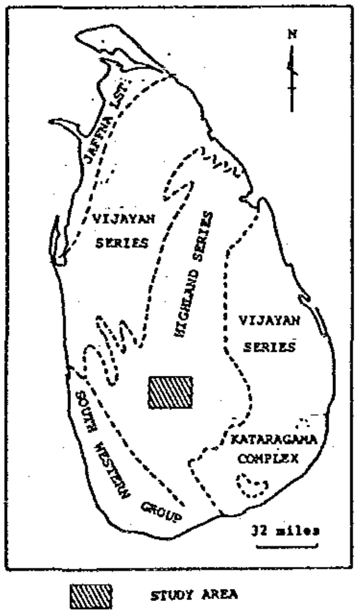
Fig. 18. Diagrammatic section across Ceylon showing the three peneplains. (*D. N. Wadia*, 1942
I—lowest, II—middle, III—highest.

3.2.3 General Geology

Stratigraphical table is shown in TABLE 3.2-2 below.

TABLE 3.2-2 STRATIGRAPHICAL TABLE FOR SRI LANKA

ERA	PERIOD	EPOCH	FORMATION
CENOZOIC	QUATERNARY	Younger Group	Coral reefs Alluvium: lake deposits Lagoonal and estuarine beds Unconsolidated sands (beach and dune) Littoral sandstone
		Older Group	Red Earth Group Ratnapura Terrace gravels beds Basal ferruginous gravel
	TERTIARY	Miocene.	Jaffna Limestone: Minihagalkanda Beds
	CRETACEOUS		Dolorite dykes
MESOZOIC	JURASSIC (Upper Gondwana)		Tabbowa Beds; Andigama Beds
PALEOZOIC			Granites and granite gneisses of Southwestern region, Pegmatites Vijayan series- Bintenne Gneisses, Wanni Gneisses, Tonigala Complex Pegmatites
PRE-CAMBRIAN			Highland series- Khondalite Group, Charnockites, Kadugannawa Gneiss, Kataragama Complex Basement rocks (not seen)



Sri Lanka geologically composes one portion of the Indian subcontinent. Metamorphic basements rocks consisting of crystalline schist, gneiss, etc. cover 90% of the country's land area. The remaining 10% is distributed largely in the northern part of the island, and consists of sediment rock of the Mesozoic Jurassic, Cenozoic Tertiary and Quaternary.

The Highest Peneplane within which the Project area is located consists of pre-Cambrian formation referred to as Highland Series, and is comprised of some of the oldest strata in the country. FIG.3.2-1 presents a general geologic profile of the study area.

Highland Series comprises four members: Khondalite group, charnokite group, Kadugannawa gneiss and Kataragama complex. However, of these only khondalite group and charnokite group are distributed in the Project area.

Khondalite group

Khondalite group consists of metamorphosed sedimentary rocks and exhibits a well stratified, banded structure. Principal rock types are:

-- Garnet - sillimonite schist and gneiss

-- Quartzite, quartz schist

-- Quartz - feldspar granulite, garnet geiss

-- Crystalline limestone

-- Graphite schist

Of these, garnet - sillimonite schist and gneiss were first discovered at Khonds in the south of India and hence the formation was given the name "khondalite". Sedimentary sequence having undergone metamorphosis characteristic of khondalite is also referred to as khondalite group.

Charnockite group

Charnockite group is composed principally of charnockite. Charnockite is a metamorphosed basic volcanic rock. It is generally massive and compact, greenish gray to bluish gray, and exhibits a glassy or greasy luster.

Type depends on chemical composition. That with SiO_2 content over 65% is referred to as leucocratic charnockite and consists mainly of quartz, feldspar, and pyroxene. Intermediate charnockite has SiO_2 content from 55% to 65% and contains mica and hornblende. Melanocratic charnockite has SiO_2 content less than 55%, is fine grained and includes principally plagioclase and pyroxene. Garnet occurs with all three types of charnockite.

The three types of charnockite are characterized by the fact that they always contain hypersthene. Charnockite is found distributed in thin beds of less than 1m thickness as well as massive beds over 100m thick, and is intercalated with thin beds of quartzite and garnet gneiss.

The geology of the Study area consists of both charnokite and khondalite, and as seen in FIG. 3.2-1, is broadly divided into three members, i.e. upper charnockite, khondalite, and lower charnockite.

Relatively thick upper charnockite is distributed at elevated areas such as mountaintops and ridgelines. Khondalite group is found at lower elevations. In the vicinity of the existing Kotmale reservoir, khondalite is distributed in a 600m thick layer, intercalated with limestone. To the south around Devon Falls, layer thickness decreases sharply to 200m. Lower charnockite is found below khondalite, and outcrops along the river at Devon and St. Clair falls. The fact that this memeber is harder than khondalite resulted in formation of the falls. The relationship between the aforedescribed members is depicted in FIG. 3.2-2.

3.2.4 Structural Geology

The principal components of the structural geology of the Study area have conventionally been considered to be a NE-SW trending fault and NW-SE trending fold structure. Under the current Study as well, several NW-SE trending folding axes and NE-SW trending prominent lineaments were identified. However, fault displacement accompanying the NE-SW lineament was not confirmed. E-W and N-S trending short lineaments were also identified.

Fold structure

The geostructural elements of the Study area were surveyed and diagramed under the Canada-Ceylon Colombo Plan Project, and are set out in the "Mahaweli Ganga Basin Geology" published in 1961.

According to this publication, the folding axes depicted in FIG. 3.2-2 are named as follows: Ramboda anticline (passing the Puna Oya), Pundal Oya syncline (8km southwest of the Ramboda anticline) and the Belton-Meddecombra anticline (located a further 8km to the southwest).

In the course of the subject Study, an additional significant syncline with good continuity was identified further to the southwest of the Belton-Meddecombra anticline. This syncline has been designated as the "St. Clair syncline" as the synclinal axis passes through St. Clair Falls.

To the southwest of the St. Clair syncline, minor folding structures of poor continuity have been identified. Also, a 2km wide zone of frequently repeating folding with N-S trending is located in the vicinity of Talawakelle. In this zone, the major folding structure of NW-SE trending becomes somewhat unclear. This zone is named Talawakelle structural bend.

Lineaments

Two lineaments of good continuity are seen in the Study area with NE-SW and NW-SE trending, respectively. The NW-SE trending lineament is assumed to reflect the folding axis. On the basis of field survey, the NE-SW trending lineament is found to be a sheared zone of almost no displacement, but is generally heavily weathered.

Due to heavy weathering and subsequent erosion, these sheared zones are clearly distinguishable; however, in most cases width is less than several meters, rarely exceeding 10m. Other lineaments of N-S trending and E-W trending have been identified in the Study area, although they are of poor continuity.

These lineaments are reflected in the drainage patterns of the area, which consist of relatively elongated patterns of NW-SE and NE-SW trending and shorter patterns of N-S and E-W trending. Consequently, the lineaments of the Study area were judged in the course of survey to be weathered fissure pattern, and no displacement was confirmed.