Ministry of Power and Energy
Ceylon Electricity Board
Democratic Socialist Republic of Sri Lanka

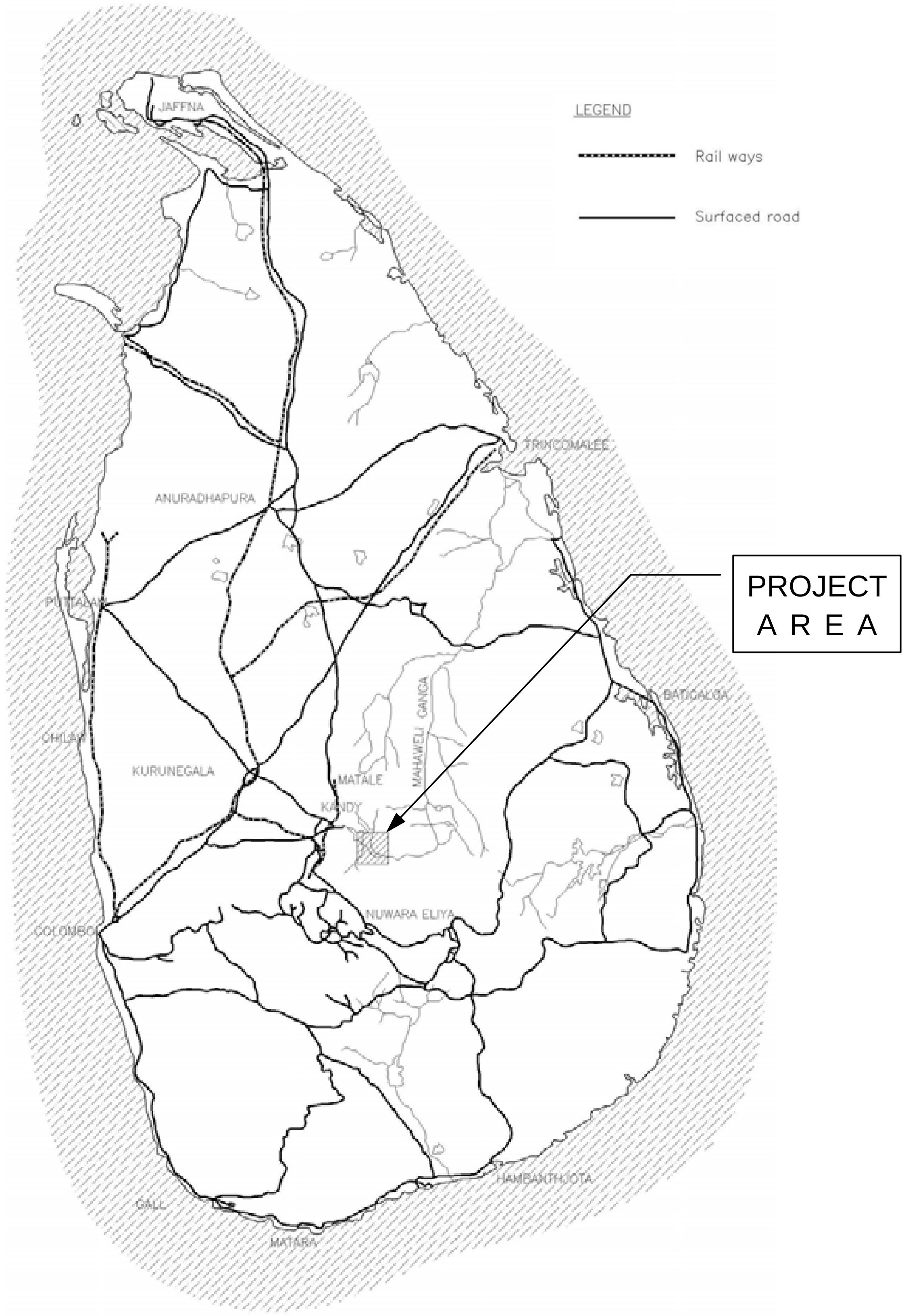
Feasibility Study for Expansion of Victoria Hydropower Station in Sri Lanka

Final Report (Summary)

June 2009

Japan International Cooperation Agency

Electric Power Development Co., Ltd.
Nippon Koei Co., Ltd.



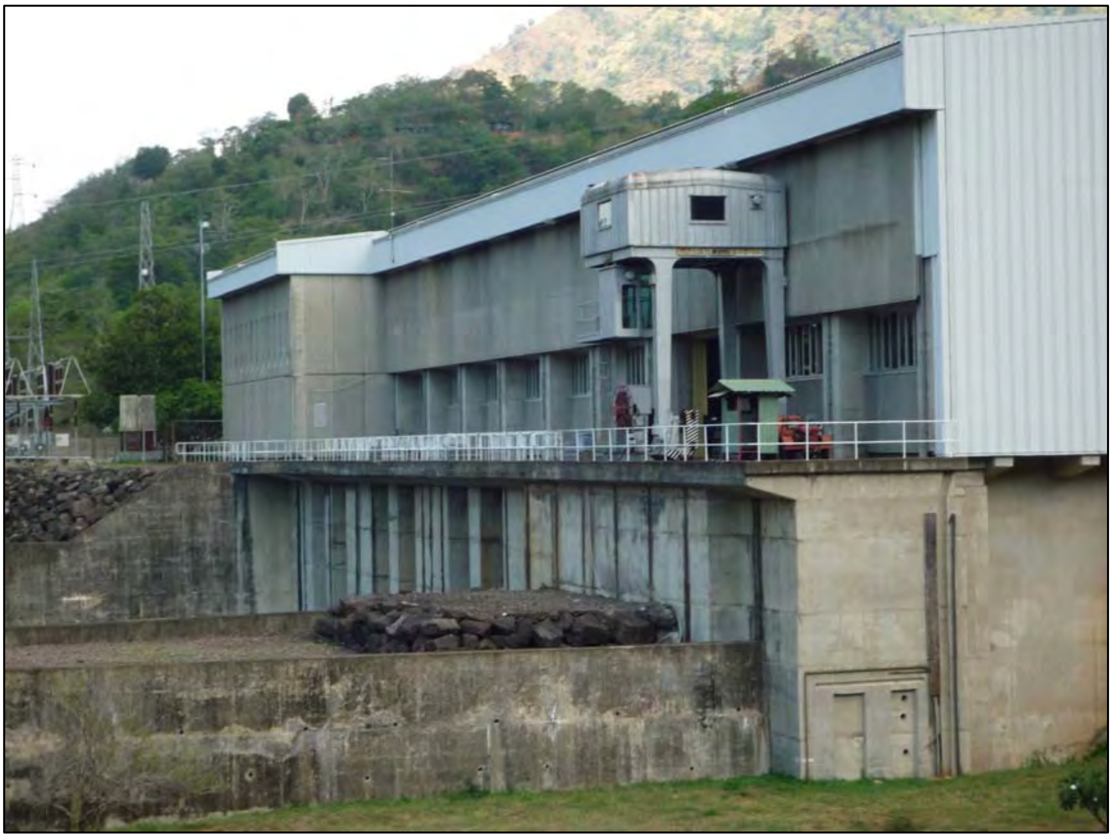
Location Map

Existing Victoria Dam

Existing Powerhouse & Switchyard

Existing Intake for Expansion

Existing Surge Tank



Existing Powerhouse

Existing Powerhouse Units

Expansion Area adjacent to Existing Powerhouse

Work Shop Held on February 11, 2009

SUMMARY

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ABBREVIATIONS

Organizations

ADB	Asian Development Bank
BOI	Board of Investment
CBSL	Central Bank of Sri Lanka
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
CIDA	Canadian International Development Agency
DAC	Development Assistance Committee
DCS	Department of Census and Statistics
DWLC	Department of Wildlife Conservation
EC	European Community
ERD	External Resources Department
FAO	Food and Agriculture Organization
GN Division	Grama Niladari Division
IDA	International Development Association
IFC	International Finance Corporation
IMF	International Monetary Fund
IPP	Independent Power Producer
JEC	Japan Electrotechnical Committee
JICA	Japan International Cooperation Agency
LECO	Lanka Electricity Company
MASL	Mahaweli Authority of Sri Lanka
MOENR	Ministry of Environment and Natural Resources
MOFP	Ministry of Finance and Planning
MPE	Ministry of Power and Energy
MSO	Mahaweli Security Organization
NGO	Non-Governmental Organization
PAA	Project Approval Agency
PP	Project Proponent
PUC	Public Utilities Commission
SPP	Small Power Producer
RDA	Road Development Authority
TEC	Technical Evaluation Committee
UNDP	United Nations Development Programme
WB	World Bank

General and technical terms

AFC	Automatic Frequency Control
B/C	Benefit-Cost Ratio
BOD	Biological Oxygen Demand
CDM	Clean Development Mechanism
COD	Chemical Oxygen Demand
CPI	Consumer Price Index
DB	Design-Build (Scheme)
D/D	Detailed Design
DP	Dynamic Program
DSCR	Debt Service Coverage Ratio
DSWRPP	Dam Safety and Water Resources Planning Project
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EL.	Elevation
EPC	Engineering-Procurement and Construction (Scheme)
F/S	Feasibility Study
FSL	Full Supply Level
GDE	Gross Domestic Expenditure
FY	Fiscal Year
GDP	Gross Domestic Product
GNP	Gross National Product
GVA	Gross Value Added
IDC	Interest during Construction
IEE	Initial Environmental Evaluation
JIS	Japanese Industrial Standards
LLCR	Loan Life Coverage Ratio
LOLP	Loss of Load Probability
MOL	Minimum Operation Level
NEA	National Environmental Act
NPV	Net Present Value
O & M	Operation and Maintenance
ODA	Official Development Assistance
OOF	Other Official Funds
PI	Project Information
PIA	Project Impact Area

S/W	Scope of Work
TDS	Total Dissolved Solid
TOR	Terms of Reference
TSS	Total Suspended Solid
VAT	Value Added Tax
VRRS	Victoria Randenigala Rantambe Sanctuary
WASP	Wien Automatic System Planning
WPI	Whole Price Index

Units

A	Ampere
ha	Hectare
Hz	Hertz (Cycles per second)
MCM	Million Cubic Meter
Mvar	Megavar
m^3/s	Cubic meter per second
NTU	Newton Turbidity Unit
pfu	Plaque-Forming Unit
ppm	Parts per million
V	Volt
kV	Kilovolt = 10^3 V
VA	Volt Ampere
kVA	Kilovolt Ampere = 10^3 VA
MVA	Megavolt Ampere = 10^6 VA
W	Watt
kW	Kilowatt = 10^3 W
MW	Megawatt = 10^6 W
Wh	Watt Hour
kWh	Kilowatt Hour = 10^3 Wh
MWh	Megawatt Hour = 10^6 Wh
GWh	Gigawatt Hour = 10^9 Wh
Rs	Sri Lankan Rupees
US$	US Dollar
Mill. US$	Million US Dollar
USc	US Cent
°C	Celsius degrees

Conclusions and Recommendations

This feasibility study (the Study) was implemented with respect to the Expansion of Victoria Hydropower Station (the Project) from January 2008, and the Project was judged feasible from technological, economical, financial and environmental perspectives as a result of the study. The details of the conclusions are discussed below.

Conclusions

(1) Background of the Study

Of around 2,000 MW which is estimated as hydropower potential in the country, 1,300 MW have been developed as of the end of 2006. However, development of hydropower is indispensable from the viewpoint of energy security of the country, which has limited domestic energy resources. In such background "the Study of Hydropower Optimization in Sri Lanka" (March 2004) was carried out under technical assistance of JICA to sort out the existing hydropower potential and to intend to optimize use of hydropower resources.

In this study, i) because it was expected that thermal power generation would necessarily take a major role in the long term, it was considered that the role of the hydropower in the country should be altered from power sources for base demand to those for peak demand, and ii) altering of the operation of existing reservoirs and power stations and expanding existing facilities were examined. The pre-feasibility study for expansion of the Victoria Hydropower Station was conducted as one of expansion projects, and possibility of the Expansion Project was confirmed.

(2) Power Demand and Power Expansion Plan

According to the demand forecast conducted with econometric model in December 2007 by CEB, required annual energy and peak demand is to grow with an average rate of around 8% per annum, respectively. Study Team confirmed that the abovementioned forecast was reasonable. CEB tentatively revised the above demand forecast by using time-trend method, because the country has been affected by the world-wide economic crisis since September 2008. Average annual growth rates of both generation and maximum power demand are smaller than those in the previous forecast, but still forecast over 6% continuously.

In the generation expansion plan for the period from 2008 up to 2022 prepared by CEB based on the revised demand forecast, power source for the peak demand is only Upper Kotmale hydropower project which is under construction.

Some of the countermeasures for the above issues, to secure the power sources for increasing peak demand, from the viewpoint of power expansion plan, are i) shifting the role of the existing hydropower plants from the base load and/or middle load to the peak load operation, and ii) expansion of existing hydropower plants. Those measures expect effective use of domestic renewable power sources.

Expansion of existing hydropower plants has some difficulties too, such as lowering of reservoir water level during the construction (suspension of generation during the construction) and economic validity, etc. On the other hand, the Project has advantages because the intake facilities for expansion have already constructed, and it is not necessary to lower reservoir water level during expansion works.

The maximum peak demand in 2008 was 1,922 MW. According to the daily load curve on the day recording the maximum demand, it is understood that about 570 MW of power sources for the peak demand was necessary. The maximum power demand in 2016 is forecast as 3,222 MW by CEB. The required power sources for the peak demand are estimated at about 960 MW, under the condition that a similar daily load curve in 2016 is similar to that in 2008. Hence new peak power sources of 390 MW will be required to arranged. However, the power source for peak duration listed in the CEB's generation expansion plan is only Upper Kotmale (150 MW). If the Project with 228 MW is considered in the plan, the Project and Upper Kotmale will almost cover the peak requirement. The Project, therefore, will contribute to coping with increase of peak power demand.

(3) Meteorology and Hydrology

The Project site is located on the middle stream of the Mahaweli river of which the basin is the largest in the country. The Mahaweli river is originating in the southwest part of the Central Highlands, flowing through the northeast part of Sri Lanka island, and effluent to the Trincomalee bay.

According to the measurement records, the average annual rainfall at the Victoria dam is 1,375 mm. The project area receives more rainfall in the northeast monsoon period, from December to February, than that in the southwest monsoon period.

The Polgolla diversion weir is located 20 km upstream of the Victoria dam. The part of flow of the Mahaweli river is diverted to the Sudu river at the weir for irrigation purpose. Release records at the Polagolla weir from 1985 to 2006 provided by MASL is used for estimate on inflow into the Victoria reservoir in the Study. Average inflow into the reservoir is estimated at 1,532 MCM/year (48.6 m^3/s).

DSWRPP assisted by the World Bank and commenced in 2008 involves optimization of water resources of the Mahaweli river including assessment of the operation policy for the diversion at the Polgolla weir. The results might give affects on the Project.

(4) Environmental and Social Considerations

The terms of reference (TOR) for the environmental impact assessment (EIA) for the Project was issued by MASL appointed as Project Approval Agency for the Project. Hence, EIA in the

Study covers both the TOR issued by MASL and JICA Guidelines for Environmental and Social Considerations.

EIA in the Study consists of i) assessment on environmental and social considerations for the three alternative options examined in the comparative study, and ii) assessment on environmental and social considerations for the optimal option selected in the comparative study. Comparison of the three alternative options from the viewpoint of environmental and social considerations was mainly conducted based on the existing data and information. The basic option mentioned in (5) is judged to be most favorable from the viewpoint of environmental and social considerations.

Hearings from habitants in the project area were conducted to ask them about their anticipated concerns on the construction works of the selected optimal option. Based on the hearing results, anticipated environmental impact items were revised.

Impact assessments were conducted based on survey results. The most anticipated social impact is drawdown of the wells near the tunnel alignment during the construction. While, the most anticipated biological issue is impact on wild elephants living in the downstream area of the powerhouse.

Regarding anticipated impacts, mitigation measures are proposed, and a monitoring plan is prepared.

Because the project area is located in the Victoria Randenigla Ramtanbe Sanctuary, temporary facilities areas and spoil bank areas are selected in consideration of results of field survey on flora and fauna so that field survey results are incorporated into layout design.

(5) Optimal Expansion Plan

The study on the optimal expansion scheme consists of i) selection of the optimal option among the CEB's three alternative options, and ii) optimization of the selected option.

The peak duration for the Hydropower Station after expansion is determined as 3 hours based on review of recorded daily and annual load curves, because it is confirmed for the Study that the Victoria Hydropower Station would be used for power source for peak demand.

The three alternative options are as follows;

1) Basic Option

The basic option is to place an additional powerhouse nearby the existing hydropower facilities.

2) Downstream Option

The downstream option is to place the surface type powerhouse 2 km downstream from the existing powerhouse. Placing the powerhouse in the downstream expects to gain an additional hydraulic head for hydropower generation.

3) Pumped Storage Option

The pumped storage option is the pumped storage power plan, using total head of 190 m between the Victoria and the Randenigala reservoirs.

The maximum discharge of the expansion power plant is estimated at 140 m^3/s which is the same as that of the existing power plant. In the case of the maximum discharge of 140 m^3/s for expansion, the upper limit of output of the expansion is to be 210 MW. Hence, 2-unit option (140 MW) and 3-unit option (210 MW) with the unit capacity of 70 MW for each alternative option are compared.

Consequently, the 3-unit option (210 MW) of the basic option is selected as optimal one from the economical viewpoint. Examinations from geological aspect and environmental aspect, and WASP analysis conclude that the basic option is optimal of the three alternative options.

Following the above, the optimizations of 210 MW class regarding i) unit capacity and the number of units, ii) normal intake water level, and iii) priority of operation for existing and expansion plants are carried out. As the results, the following is selected:

- Number of unit .... 2 units
- Normal intake water level .... EL. 430 m
- Operation rule of existing and additional units .... Same operation for existing and expansion plants.

(6) Outlines of Proposed Expansion Plan

Based on the result in **(5)** above, the Project is to connect the existing intake for the expansion and a new powerhouse to be located next to the existing powerhouse with a waterway parallel to the existing waterway.

Water for generation of 140 m^3/s is to be taken at the existing intake for the expansion and led through the headrace tunnel and penstock to the surface type powerhouse. The installed capacity is 228 MW with 2 units, and 716 GWh of annual energy are obtained with the existing and expansion power facilities (210 MW and 228 MW). Power generated is evacuated to the CEB grid through the existing transmission lines.

(7) Basic Design

The design in the Study is carried out at more detailed level than conducted in a feasibility study on a hydropower project, in accordance with S/W (Scope of Work) for the Study. In the basic design, salient features of civil structures and electromechanical equipment for the optimal development scheme selected in (5) are examined, and drawings are prepared. Following that, the construction planning, estimate of the project cost, and preparation of implementation schedule are conducted.

Open-air works and underground works of the Project are to be carried out near the existing Victoria dam, intake facilities, waterway and powerhouse. Hence, vibrations caused by blasting should be controlled to prevent them from being damaged due to the blasting. The maximum allowable blasting vibration is determined as 2 cm/s, in consideration of a value by elastic theory, allowable limits specified in a manual for tunnel works in Japan, values applied to railway and road tunnels in Japan, value applied to hydropower expansion projects in Japan, etc. The blasting vibration limit is incorporated into examinations on tunnel alignment and into construction planning.

The main structures consist of the headrace tunnel, surge tank, penstock and powerhouse. The existing intake for the expansion is to be connected to powerhouse through the headrace tunnel with around 5,000 m in length and 6.6 m in inner diameter, surge tank, and 1-line tunnel and 2-line open-air penstock with 6.6 m to 2.85 m in inner diameter. The powerhouse with 37 m in width, 44 m in height and 69 m in length is to be constructed next to the existing powerhouse. After generation, water used for generation is to be discharged to the Mahaweli river through the outlet.

(8) Construction Cost and Construction Schedule

The total project funding required is approximately US$222 million, as of October 2008, including the direct cost consisting of costs for preparatory works, civil works, hydromechanical equipment, and electromechanical equipment, and indirect cost such as environmental expenditures, construction administrative cost and engineering fee, and contingencies for variable quantities.

The construction period from the start of the preparatory works to the start of operation is estimated at 52 months (4 years and 4 months). The Project is scheduled to be commissioned at the end of 2016.

The DB (Design-Build) schemes in which the construction work including the detailed design is ordered in a lump sum, as recently introduced for thermal power projects, could be applicable because the Project has less unforeseeable physical risks involved in hydropower project than a hydropower project generally has. Hence, the DB and the conventional scheme (i.e. Contractor is determined by the bid after consultants execute the detailed design) are compared, and as a result the conventional scheme is recommended.

(9) Economic and Financial Evaluation

In the Study, economic evaluation is performed in consideration of the benefit as the saved cost of alternative thermal power project. The Economic Internal Rates of Return (EIRR) was estimated at 19.8% which exceeded the opportunity cost of capital of 10%. Thus the Project was evaluated to be economically feasible. As the results of the sensitivity analysis, EIRR would 10%, even if the average fuel costs in the period from January up to October 2008 decrease by 72%, and it is also confirmed to be feasible.

Financial benefit of the Project is the revenue to be earned by the electricity sale. Financial Internal Rates of Return (FIRR) on the total investment is estimated at 9.6%. It is found out that the Project is to be financially feasible, when a concessional loan is provided.

Recommendations

The Victoria Hydropower Expansion Project has an advantage of not having the need to lower reservoir water level during a construction period for expansion, because the intake facilities for the expansion were already constructed during the construction of the existing power generation facilities. In addition, construction cost per kW of the Project is less than 50% of those of other candidate hydropower projects, and development of the Project expects effective use of domestic renewable power sources. The Project, therefore, should be promoted as a candidate for the next hydropower project.

The Project is feasible from technical, economic/financial and environmental perspectives and can be developed as a power generation project which will also contribute to coping with increasing peak demand. The operation can begin around at the end of 2016, given the time required for tasks to take place subsequent to this Feasibility Study, including funding arrangement, geological investigations, detailed design and construction works. The following will have to be conducted before implementing the Project:

(1) As mentioned in **Chapter 10** of the main report, it is possible that loans to both the detailed design and the construction works will be provided at the same time, because the Project has i) less unforeseeable physical conditions such as geology, in comparison with usual hydropower projects, ii) less restriction for reservoir operation during expansion works and iii) no resettlement. Formulation of the Project such as listing it in the CEB's generation expansion plan after the completion of the Study and then financial arrangements are required.

(2) It is necessary to confirm the following issues before implementation of the Project as described in **12.1** of **Chapter 12** in the main report;

1) Because the existing Victoria Hydropower Station is being used for both peak and base power sources, i) base demand in the commissioning year of the Project will be satisfied with new power sources, based on the CEB's latest power demand forecast and power expansion plan, and ii) candidate power stations for system frequency adjustment are nominated.

2) The diversion policy at the Polgolla weir and irrigation demand in the downstream area is to be almost concluded in the Dam Safety and Water Resources Planning Project.

(3) In the detailed design, the results of additional investigations as shown in **12.3** of **Chapter 12** in the main report should be sufficiently incorporated and at the same time documents for bidding and contracting of construction works with a higher accuracy of construction cost estimates should be prepared.

(4) Bidding for construction works, and the selection of contractors will have to be performed before the construction of the Project. In addition, preparatory works such as the improvement of the existing roads will have to be completed before the construction launch of the Project.

(5) It is indispensable that conditions of the existing structures, houses, etc. to be affected by blasting during the construction, should be investigated and recorded immediately before the commencement of the construction works. A monitoring plan on blasting should be prepared during the detailed design stage.

Salient Features of Victoria Hydropower Expansion Project

Item		Dimension
Reservoir (Existing)	Name of River	Mahaweli river
	Full Supply Level	438.0 m
	Minimum Operation Level	370.0 m
	Available Depth	68.0 m
	Gross Storage Capacity	722×10^6 m^3
	Effective Storage Capacity	688×10^6 m^3
	Design Flood	9,510 m^3/s
Dam (Existing)	Type	Concrete Arch Dam
	Height of Dam	122 m
	Length of Dam Crest	520 m
	Volume of Dam	480×10^3 m^3
Intake for Expansion (Existing)	Number	1
	Type	Inclined Intake
Headrace Tunnel	Number	One (1)
	Inner Diameter	6.6 m
	Total Length	5,003 m
Surge Tank	Type	Restricted Orifice Type
	Diameter	20.0 m (Upper Section) 6.6 m (Lower Section)
	Height	117.0 m (Upper Section) 32.9 m (Lower Section)
Penstock	Type	Tunnel & Open-air
	Number	Tunnel: One (1) Open-air: Two (2)
	Inner Diameter	Tunnel: 6.6 m to 5.6 m Open-air: 3.95 m to 2.85 m
	Length: Tunnel	575 m
	Length Open-air	175 m for Unit 4 160 m for Unit 5
	Total Length	750 m for Unit 4 735 m for Unit 5
Powerhouse	Type	Surface type
	Size	37m wide × 44m high × 69m long
Development Plan	Normal Intake Water level	430.0 m
	Normal Tail Water Level	231.2 m
	Gross Head	199.0 m
	Effective Head	183.3 m
	Maximum Discharge	140 m^3/s
	Number of Unit	Two (2)
	Install Capacity	228 MW (only expansion)
	Peak Duration Time	3 hours
	95% Dependable Capacity	393 MW (with existing)
	Annual Generation Energy	716 GWh (with existing)
	(Firm Energy*)	468 GWh (with existing)
	(Secondary Energy**)	248 GWh (with existing)

Item		Dimension
Turbine	Type	Vertical Shaft, Francis Turbine
	Number	Two (2)
	Rated Output	122 MW per unit
	Revolving Speed	300 r/min
Generator	Type	Three-phases, Synchronous Generator
	Number	Two (2)
	Rated Output	140 MVA per unit
	Frequency	50 Hz
	Voltage	16.5 kV
	Power Factor	0.85 lag
Main Transformer	Type	Outdoor Special Three-phase Type or Outdoor Single Phase Type
	Number	Two (2)
	Capacity	145 MVA per unit
	Voltage	Primary 16.5 kV
		Secondary 220 kV
	Cooling	Natural Convection Oil Forced Air Type
Switchyard	Type	Conventional Type
	Bus System	Double Bus
	Number of Lines Connected	Three (3) cct Transmission Lines
	Voltage	220 kV
Construction Period Including Preparatory Works		52 months (4 years and 4 months)
Project Cost		US$222 million

Note: * *"Firm energy" means the total of power generated during 3-hour peak duration.*
** *"Secondary energy" means the total of power generated in duration except 3-hour peak time.*

Chapter 1 Introduction

The annual maximum demand in Sri Lanka had grown at the rate of 6.9% in average from 1996 to 2006, and CEB forecasts that its growth rate will keep at around 6% in the next decade. Development of peak power resources in the country is one of the most important issues in the power sector.

Of around 2,000 MW which is estimated as hydropower potential in the country, 1,300 MW have been developed as of the end of 2006, and the number of remaining project sites that have potential from the viewpoints of economic efficiency and the natural/social environment is limited. However, development of hydropower is indispensable from the viewpoint of energy security of the country, which has limited domestic energy resources. In such background “the Study of Hydropower Optimization in Sri Lanka” (March 2004) was carried out under technical assistance of JICA to sort out the existing hydropower potential and to intend to optimize use of hydropower resources.

In this study, i) because it was expected that thermal power generation would necessarily take a major role in the long term, it was considered that the role of the hydropower in the country should be altered from power sources for base demand to those for peak demand, and ii) altering of the operation of existing reservoirs and power stations and expanding existing facilities were examined. The pre-feasibility study for expansion of the Victoria Hydropower Station was conducted as one of expansion projects, and possibility of the Expansion Project was confirmed.

The Expansion Project has an advantage of not having the need to lower reservoir water level during a construction period for expansion in comparison with other expansion projects of hydropower stations, because the intake facilities for the Expansion Project were already constructed during the construction of the existing power generation facilities.

In these circumstances, the Government of Sri Lanka requested the Government of Japan to conduct a feasibility study (the Study) for the Expansion of Victoria Hydropower Station (the Project). In response to the request, JICA, the executing organization of technical assistance of the Government of Japan, conducted a project formation study in August 2007. S/W was concluded between MPE/CEB and JICA on November 19, 2007.

The Study aims at formulating the optimum plan and assessing its technical, economic and financial, and environmental viabilities of the Project located in Central Province, at carrying out the technology transfer to Sri Lankan counterpart personnel in the course of the Study and at recommending further process of the project implementation.

The Study was commenced in January 2008 and has been completed in June 2009 when the final report on the Study was submitted.

Chapter 2 General Information of Sri Lanka

2.1 Geography

Sri Lanka is an island country in the Indian Ocean, located to the south of the Indian subcontinent. The main island lies between 5°55´ and 9°55´ north latitude and between 79°42´ and 81°52´ east longitude, and stretches for about 240 km in the east-west direction and 435 km in the north-south direction. The area of the country is 67,095 km^2 including the internal waters of 1,170 km^2.

The topographic features of Sri Lanka are categorized in three zones on the basis of elevation: a central mountainous area called as the Central Highlands, the plains, and the coastal belt.

The rivers of Sri Lanka radiate from the Central Highlands to the sea. There are 16 principal rivers longer than 100 km in length, with 12 of them carrying about 75 percent of the mean river discharge in the entire country. The longest river is the Mahaweli Ganga (335 km), and the Aruvi Aru (164 km) follows. In the Central Highlands, river courses are frequently broken by discontinuities in the terrain, and where they encounter escarpments, numerous waterfalls and rapids have eroded a passage. Once they reach the plain, the rivers slow down and the waters meander across flood plains and deltas. The upper reaches of the river are wild and usually unnavigable, and the lower reaches are prone to seasonal flooding.

2.2 Climate

The climate of Sri Lanka is categorized as tropical as a whole. The annual average temperature in Colombo is about 27°C. At higher elevations, however, it is quite cool, and the annual average temperature goes down to about 15°C in Nuwara Eliya at about 1,800 m above sea-level.

The rainfall pattern is influenced by the monsoon winds of the Indian Ocean and Bay of Bengal and is marked by four seasons. The first season is from mid-May to October, when winds originate in the southwest, bringing moisture from the Indian Ocean. When these winds encounter the slopes of the Central Highlands, they unload heavy rains on the mountain slopes and the southwestern area of the island. However the leeward slopes in the east and northeast receive little rain. The second season occurs in October and November, the inter-monsoon season. During this season, periodic squalls occur and sometimes tropical cyclones bring overcast skies and rains to the southwest, northeast and eastern parts of the island. During the third season, December to March, monsoon winds come from the northeast, bringing moisture from the Bay of Bengal, unloading heavy rains on the northeastern slopes of the mountains. Another inter-monsoon period occurs from March to mid-May.

2.3 Government

The president, who is elected directly for a six-year term, serves as the head of state. In Sri Lanka, the president also serves as the head of government and appoints cabinet ministers in consultation with the prime minister. As of March 2008, there were 58 ministries of cabinet rank; the CEB belongs to the Ministry of Power and Energy.

The legislative branch of the government is unicameral, and the Parliament consists of 225 seats. The members of Parliament are elected by popular vote on the basis of a modified proportional representation system and serve six-year terms.

The administrative divisions of the country consist of 9 provinces, and 25 districts under these provinces. The smallest administrative unit is the Assistant Government Agent of Divisions (AGA Division), and there are 247 AGA Divisions in the country. The Victoria Hydropower Station is located in Nuwara Eliya District in Central Province.

2.4 Population

The latest demographic survey was made by the Department of Census and Statistics (DCS) under the Ministry of Finance and Planning in July 2001, but its aggregation does not include population of North and East Provinces.

The population in 2001 was 18.80 million, and the average annual growth rate was calculated at 1.19% for 20 years from 1981.

Population density was around 333 persons per km^2 in 2001.

2.5 Macro-economy

2.5.1 National Accounts

The gross domestic product (GDP) in Sri Lanka was Rs.2,484 billion at current factor cost prices in 2006. Among major economic sectors, “trade, restaurant & hotels” sector recorded the largest gross value added (GVA) of Rs.496 billion, the highest contribution to the national economy, accounting for 20% of GDP. This sector’s percentage contribution to GDP has decreased for the recent 10 years.

An economic sector of “agriculture, forestry & fishery” accounted for Rs.409 billion or 16.5% of GDP, the second position in GDP contribution. The sector has decreased its GDP contribution gradually.

Following them, “transport and communication” sector occupied the third position, accounting for Rs.361 billion or 14.5% of GDP. The manufacturing sector had the third position in GDP contribution up to 2005 but has gone down to the forth position in 2006 due to increase of GVA of “transport and communication”.

GDP per capita was Rs.218,200, equivalent to around US$2,014 as an annual average in 2008. It has grown steadily after 2003 in US Dollar basis, although it dropped down to a minus rate because of a negative growth in 1999 and in 2001.

2.5.2 External Trade and Balance of Payment

Sri Lanka has traditionally run a deficit in current account until 2008. The merchandise trade recorded to keep the balance in deficit for long time. The trade balance in deficit has increased rapidly since 2006, because of increase in import goods caused by reconstruction activities against the tsunami damages and good economic performance in the country, and price raise of imported goods including crude oil. On the other hand, services balance and transfers including workers' remittance have kept a level of surplus. As a result, thus, the current account balance has recorded deficit consecutively.

Capital account has exhibited a surplus owing to long-term receipts. Long-term financial accounts have kept a surplus, although they fluctuated year by year. Short-run financial accounts have extremely been unstable in a balance. Then, the over-all balance has resulted in keeping a moderate balance, i.e., making up the deficit of current account and debt repayment by means of inflows of long-term loans.

It is worthy to note that the amount of the direct investment has drastically increased since 2006.

Sri Lanka's external trade has kept the balance in deficit as discussed above. Its trade structure has kept a traditional pattern as i) exporting commodities such as tea, rubber, coconuts, etc., and light industrial products like textiles, garments, petroleum products, etc., and ii) importing consumer goods like rice, wheat, sugar, etc., intermediate goods like petroleum, fertilizer, etc., and investment goods like machinery, transport equipment, etc. It is said that this external trade is a typical external trade structure of developing countries. Therefore, the external environment in international markets for commodities and industrial products is a potent influence not only to Sri Lanka's external trade but also to the national economy.

Regarding share rates of external trade by trading commodities, industrial commodities including textile & garments, petroleum products and others are the highest ones for export showing constantly 70% or more in share rate to the total export amount since 1998. The second one is the agricultural commodities including tea, rubber, and coconut with around 20% on average for the same period.

On the other hand, intermediate goods including petroleum, fertilizer, textiles & clothing, etc. are the highest ones for import with constantly 50% or more in share rate to the total import amount. The second ones are investment goods including machinery, transport equipment, building materials and others with around 22% of share rate on average to the total import amount.

2.5.3 Government Finance

In Sri Lanka, a fiscal year starts from January 1 and ends on December 31 in the same year, i.e., the same as calendar year. In 2007 and 2008, the Government finances of Sri Lanka amounted to Rs.565.1 billion and Rs.655.3 billion in revenue and Rs.841.6 billion and Rs.996.1 billion in expenditure. Thus, the balance of these fiscal operations was resulted in deficit as 277.6 billion in

2007 and 340.9 billion in 2008. These deficits were financed by borrowings, as enumerated in the table. The deficit in 2008 corresponded to 7.7% of GDP in the same year.

Taxes on goods and services share at around 90% to the total revenue in both 2007 and 2008. Current expenditures occupied a share of 74% in 2007 and 75% in 2008.

2.5.4 External Debt and Outstanding

(1) Foreign Assistance

Net receipts of official development assistance (ODA) from member nations of DAC multilateral agencies, and others aggregated to US$4.11 billion in total for the seven years from 2000 through 2006. The receipts fluctuated year by year. The receipts in 2006 accounted to US$800 million. During the above period, Japan was the top donor of ODA to Sri Lanka.

An annual receipt of ODA accounted for approximately 2.8% of GDP in 2006. The average annual net receipt for the seven years in the above period accounted for 2.8% of GDP and for around 18% of an annual expenditure of the central government.

(2) External Debt and Outstanding

In 2006, the total external debt outstanding was US$11.4 billion, accounting for 42% of GDP. The outstanding debt has exceeded US$10 billion since 2004. The total debt-service in 2006 was US$960 million, comprising US$700 million of principal repayment and US$260 million of interest payment.

The debt-service ratio (DSR), a kind of country risk assessment factors, has been from 7.9% in 2005 to 14.7% in 2000. Thus, DSR has kept a sound position in terms of external debt problem, because those were always lower than the level of 20%, the critical level of DSR.

2.5.5 Price Index and Exchange Rates

(1) Price Index

The consumer price index (CPI) in Sri Lanka increased to 249.5 (base: 1995 to 1997 = 100) in 2007. Then, the CPI increased twice during the period from 1999 up to 2007. Thus, an annual inflation rate was calculated at 9.2% on average. During the same period, the maximum inflation rate was 20.4% in 2001 and the minimum one was 1.5% in 1999.

(2) Exchange Rates

The annual average exchange rate of Rupee dropped down from Rs.55.27 per US$ in 1996 to Rs.108.33 in 2008.

Chapter 3 Power Sector Survey

3.1 Organization

Almost all of the power utilities in the country including generation, transmission and distribution are conducted by CEB established in 1969.

Small Power Producers (SPPs) which owns hydropower plants less than 10 MW and Independent Power Producers (IPPs) which own thermal power plants participate in the generation activities, in addition to CEB. Distribution is managed regionally by two organizations which are CEB and LECO established in 1983. CEB belongs to the Ministry of Power and Energy which manages national power and energy policies.

3.2 Existing Power Plant

As of July 2008, the total installed capacity in Sri Lanka is 2,445 MW. It is composed of 1,756 MW owned by CEB, 659 MW by private sector (IPPs and SPPs), and 30 MW by a short-term contractor from the viewpoint of ownership. CEB shares 72% of in the total installed capacity. From the aspect of power sources, it consists of hydropower with 1,314 MW (53.7%), thermal power with 1,098 MW, and wind power with 3 MW.

3.3 Existing Transmission Line and Substations

The transmission line voltages with 220 kV and 132 kV are adopted in Sri Lanka.

CEB's power system is controlled at the System Control Center located in Dematagoda. The main 220 kV transmission system passes from Mahaweli complex including Kotmale, Victoria, Randenigala and Rantambe hydropower stations through Kotugoda, Pannipitiya and Biyagama substations to the main load center.

132 kV transmission line system is used for intermediate connections among other hydropower stations, thermal power stations and substations.

220/132/33 kV and 220/132 kV transformers are installed in Rantambe, Biyagama, Kotugada, New Anuradhapura, Pannipitiya and Kelanitissa substations.

There are 37 substations with 132/33 kV and four 132/11 kV indoor Gas Insulated Switchgears (GIS) installed at Fort, Kollupitiya, Maradana and Havelock substations.

3.4 Actual Results of Power Supply and Demand

3.4.1 Power Demand

(1) Generation and Peak Load

The annual peak load and generation were 1,893 MW and 9,389 GWh in 2006, respectively.

Under stable growth of social economic situation in the country from 1996 to 2006, the annual average growth rate of annual peak load and generation showed 6.9% and 7.2%, respectively.

(2) Energy Demand (GWh) by Category

The energy demand of CEB is categorized to six in the same way as tariff category, as follows:

Category: 1. Domestic, 2. Religious, 3. General, 4. Industrial, 5. Bulk Supply to LECO,

6. Street Lighting.

Actual result of domestic energy demand was 2,579 GWh (32.9%) and industrial energy demand was 2,605 GWh (33.3%) in 2006. The total demand of domestic and industrial sectors in 2006 is sharing 66% of the total power demand.

The share of industrial power demand has maintained constantly during the past 10 years, while domestic power demand grew with 4.3% per annum and has become the same share as that of industrial in 2006.

(3) Monthly Maximum and Minimum Load

The annual peak demand is recorded in April to May or in November to December in Sri Lanka, but monthly fluctuation of the maximum and minimum load is not large.

(4) Daily Load

The daily peak load in the country is recorded in the evening (6:00 p.m. to 9:00 p.m.), and it shows the typical domestic power demand pattern.

(5) Daily Load Curve by Power Source

Power sources for the base load are mainly composed of IPPs' and CEB's thermal power plants, middle load is supplied by CEB's middle class hydropower plants, and peak load is mainly controlled by reservoir type hydropower plants which are applied for compensation of short term load fluctuation and important power plant for stable operation of the power system.

(6) Annual Power Generation

The annual power generation in the country is increasing steadily, recording 6,520 GWh in 2001, 8,769 GWh in 2005 and 9,389 GWh in 2006.

(7) Maximum Power Demand

The maximum power demand in the country as of the end of 2008 is 1,922 MW recorded on May 21, 2008.

From 1997 to 2006, the annual maximum power demand (MW) is increasing by 6.9% per annum steadily.

3.4.2 Power Supply

(1) Generation by River Basin

The Mahaweli Complex to which the Victoria Hydropower Station belongs shares 22.6% of all power generation in 2006. This shows the complex plays an important role of power supply in power sources of the country.

(2) Load Factor by Different Power Sources

Yearly and monthly load factors are calculated based on average power generation in the year 2006 and in the month of May 2006, respectively.

Load factor of all generation including that by thermal power plants is 57%, while the load factor of the Mahaweli complex is 41.7% for the year of 2006 and 30.6% for May 2006.

It means that the power plants of the Mahaweli complex, as a whole, are used for peak operation rather than other power sources.

3.5 Electricity Tariff

The electricity tariff system of CEB consists of two parts, demand plus fixed charge and energy (unit) charge. For a long time, the tariff had six categories: Domestic, Religious, General, Industrial, Bulk Supply to LECO and Street Lighting, however, another new category, Hotel, was added in a tariff revision in 2006. Formerly there was a cross subsidy from industrial and general use consumers to the domestic and religious consumers, however, the cross subsidy was gradually abolished with the tariff revision in 2006.

Tariff revision in recent years was made as follows: 2002 (April and August); 2006 (February and September); 2007 (February) and 2008 (March). As there was no revision for four years since 2002, the substantial increase in tariff was obliged consecutively in 2006 and 2007. Due to the fact that CEB relies on the thermal power generation which requires costly fuels, current tariff level does not cover the required cost. **Table 3.4.2-1** shows the general average unit tariff of CEB for the past six years.

Table 3.4.2-1 General Average Unit Tariff of CEB

Year	Energy Sales (GWh)	Sales income (Million Rs.)	Unit rate (Rs./kWh)	Annual Increase
2002	5,500	40,544	7.37	
2003	6,209	47,719	7.69	4%
2004	6,667	51,119	7.67	0%
2005	7,255	55,978	7.72	0%
2006	7,832	69,941	8.93	16%
2007	8,276	87,400	10.56	18%

Source: Statistical Digest 2002-2007, CEB

3.6 Financial Situation of CEB

Electricity sales by CEB have been steadily grown for the past five years. The main reason is the annual increase of electricity sales by 8%. In addition, electricity tariff revision in 2002 and 2006 contributed largely in increase in income. Even with these recent tariff revisions, however, it does not reach to a level to recover the required cost.

On the other hand, the direct cost increases much more than the increase in electricity sales revenue. There are two major reasons for this cost increase: one is the increase of cost, especially fuel cost hike, in thermal power plants owned and operated by CEB since 1997; the other is the increase in power purchase cost from IPPs.

Due mainly to such situation, CEB has been producing no profit since 2000, and the amount of deficit has been increasing annually.

3.7 Review of Structure of Power Sector

(1) Structure of Power Sector

CEB and LECO operate as electric utility in Sri Lanka.

CEB was established as a public power corporation by an act in 1969. CEB belongs to the Ministry of Power and Energy, and is in charge of generation, transmission and distribution. Nowadays 39.5% of the required energy comes from the power plants operated by IPPs.

LECO is a power distribution company established by the law in 1983. Major shareholders are CEB and Ministry of Finance. LECO receives bulk supply from CEB and supplying to the western coastal region between Negombo and Galle, covering approximately 400,000 consumers.

Public Utilities Commission (PUC) was established by law in 2002 as a regulator. It inaugurated in 2003 to cover the energy (electric power and petroleum) and water sectors. PUC is to implement regulations on these sectors only after enactment of the relevant laws. The Sri Lanka Electricity Bill was passed in Parliament in March 2009.

(2) Current Situation of Power Sector Reform

CEB was established as a government corporation in 1969. The Government of Sri Lanka, in 1997, decided to restructure the power sector drastically in order to overcome accumulated inefficiencies in the CEB. It is expected that this reform process will improve the operating efficiencies of each entity, and secure financial soundness. As a consequence, the reliable and high-quality supply of electricity will be available to consumers at affordable prices.

The Sri Lanka Electricity Bill, passed in March 2009, does not touch on the controversial unbundling of CEB any more, but to forward steadily the regulatory reform of the power sector which may be agreeable among the parties concerned. Thus the main point is to vest the PUC authority in licensing to the public utilities and approval of electricity tariff revision, among others.

On the other hand, structure of CEB without unbundling should have Functional Business Units (FBU) in generation, transmission and distribution, and works to set the Key Performance Indicators have been underway.

(3) Problems in Power Sector in Sri Lanka

Lots of problems had been pointed out for Power Sector in Sri Lanka. Power Sector has a lot to be solved and so much endeavor has been undertaken for a better solution. It is still on the way.

The following include the major problems in Power Sector:

- Current electricity tariff lies in the higher level in the region.
- CEB owns and operates thermal power plants with the higher fuel costs.
- CEB purchases energy from IPP with higher cost than its average electricity rates.
- CEB formulates Long Term Generation Expansion Plan annually but the plan has not been implemented due to circumstances.

Chapter 4 Power Development Plan

4.1 Load Demand Forecast

CEB revises annually the national load demand forecast, using an econometric model. In **Section 4.1.1**, CEB's demand forecast for the period from 2007 up to 2027 issued in December 2007 is described. For the purpose of the review of CEB's demand forecast, Study Team carried out a load demand forecast as mentioned in **4.1.2**. Both demand forecast results are compared in **4.1.3**.

CEB revised the above national load demand forecast by using a time trend method, because the country has been affected by the world-wide economic crisis since September 2008. The revised demand forecast is mentioned in **4.1.4**.

4.1.1 Load Demand Forecast by CEB

In this section, conditions for the forecast, a demand model, and the results of the load demand forecast study by CEB are described:

(1) Demand Model

In the demand model applied by CEB to the demand forecast, the consumers are classified into three categories, and the parameters for each category as shown below:

1) Domestic: Past Demand, GDP per capita, Population, Average Electricity Tariff, Domestic Consumer Account.
2) Industrial and General Purpose: Past Demand, GDP, Population, Average Electricity Tariff, Industrial Consumer Account.
3) Others (Religious purpose and Street Lighting): Past Demand

Regarding population, the forecast by DCS (Department of Census and Statistics) is used for the demand forecast.

GDP forecast from 2007 up to 2011 by the Central Bank of Sri Lanka and that after 2011 by CEB based on trend up to 2011 are used.

The average electricity tariffs in future for the domestic category is estimated by using CCPI (Colombo Consumer Price Index) and that for the industrial and general purpose is done by WPI (Wholesale Price Index), respectively.

(2) Demand Forecast Scenarios

CEB forecast demand in the five load forecast scenarios, which was to be used for inputs to Long Term Generation Expansion Plan, as sensitivity studies. They are as follows:

1) Scenario 1 : Low Load Forecast: Considering low population growth and low GDP growth.
2) Scenario 2 : Base Load Forecast: Considering base population growth and base GDP growth
3) Scenario 3 : High Load Forecast: Considering high population growth and high GDP growth

4) Scenario 4 : Forecast with Constant Energy Losses: Considering base load growth with constant energy loss 16.6% on 2) Scenario 2.

5) Scenario 5 : Forecast with DSM (Demand Side Management): Considering saving the Energy and Peak Demand by DSM measures on 2) Scenario 2.

In Scenario 2 as the base case, under the conditions of the population growth rate with 0.59% per annum and GDP growth rate with 6.7% per annum, energy demand is estimated to grow from 8,258 GWh in 2007 to 40,615 GWh in 2027 with the annual average growth rate of 8.29%.

The maximum power demand is estimated to grow from 1,986 MW in 2007 to 9,038 MW in 2027 with the annual average growth rate of 7.9%. The load factor is estimated at 59.7% in 2027.

4.1.2 Load Demand Forecast by Study Team

From the viewpoint of review of the load demand forecast conducted by CEB, “macro approach” concept which uses an explanatory parameter was used in this study.

In order to decide the explanatory parameter to be used for the demand forecast study, GDP, Consumer Price Index (CPI), and Wholesale Price Index (WPI), and the population are chosen for examination, and the correlation between energy demand and each parameter is calculated.

(1) Consumer and Wholesale Price Indices

Correlation of past 10 years’ energy demand and price indices (CCPI and WPI) was confirmed.

Correlations between energy demand and each index were around 96% and 97%.Price index is not always assured to reflect energy demand fluctuations under the unstable worldwide economic situation, so the CPI and WPI should not be applied to long term forecast over 10 years in the country.

(2) Population

In the same way as the price indices above, the correlation between energy demand and population was examined.

Energy demand has increased 10 times of the growth rate of population. The correlation factor between energy demand and population was around 91% and is not so high in comparison with that of GDP mentioned in the next sub-section. It is not adopted as explanatory parameter for the demand forecast.

(3) GDP

The correlation between energy demand and GDP was examined for the past 10 years (1997-2006).

It was confirmed that GDP had high correlation with the energy demand in the past in a form of parabola. The correlation coefficient was 99.85%.

As a result of the above, GDP had the best correlation with energy demand, and Study Team decided to adopt GDP as the explanatory parameter for demand forecast.

4.1.3 Load Demand Forecast by CEB and Study Team

Energy demand from 2007 to 2020 including 2016 in which the Victoria expansion project is expected to be completed is estimated by Study Team by using GDP as explanatory parameter.

As the result of forecasting by Study Team, generation (GWh) in 2020 is 27,838 GWh, and average annual growth rate is 8.03%. While, in the CEB’s forecast those are 27,763 GWh and 8.02%, respectively. Hence, the results of the forecast by Study Team are similar to those by CEB.

Forecast of the peak load (annual maximum demand) in 2020 is estimated at 5,425 MW by Study Team, while that in CEB’s forecast is 5,400 MW. Annual average growth rate of both forecasts is 7.79% and 7.77%, respectively.

Consequently the forecast by Study Team has almost the same result as that by CEB. Therefore, the energy demand forecast by CEB is confirmed to be reasonable.

4.1.4 Revise of Load Demand Forecast by CEB

Since September 2008, Sri Lanka has been also affected by the world-wide economic crisis. Hence revision of the power demand forecast becomes necessary. By using a time trend method, generation (GWh) and maximum power demand (MW) up to 2028 were revised by CEB.

Average annual growth rates of both generation and maximum power demand are smaller than those in the previous forecast mentioned in **4.1.1**, but still forecasted over 6% continuously. In the Study, this revised demand forecast reflecting the latest economic situation is used.

4.2 Development Plan

4.2.1 Generation Expansion Plan by CEB

To meet the requirements of an increase in peak load and required energy, as per the load forecast, CEB annually prepares a long term power expansion plan. The latest generation expansion plan for the period from 2008 to 2022 has been established by CEB in February 2009, based on the demand forecast mentioned in **4.1.4**.

If the projects listed in the expansion plan are developed and commissioned on schedule, the margin will be secured as 15% to 30%. It should be noted that the listed projects after 2013 have not been committed.

Newly developed power sources for the peak demand is only the Upper Kotmale Hydro Power Plant with 150 MW scheduled to be commissioned in 2012.

4.2.2 Justification Observed Based on the Power Development Plan

Although all power plants until 2012 have been committed or under construction in the power expansion plan for the period from 2008 up to 2022, the power plants to be commissioned after 2013 have not been committed for peak demand. New thermal power plants for peak load operation are facing difficulties because of the remarkable worldwide fossil fuel price increase.

The countermeasures for the above issues, to secure the power sources for increasing peak demand, from the viewpoint of power expansion plan, are i) development of new hydropower projects, ii) shifting the role of the existing hydropower plants from the base and/or middle load to the peak load operation, and iii) expansion of existing hydropower plants. Those measures expect effective use of domestic renewable power sources.

However, the number of possible development of new hydropower plants is limited and there might be no large size development project. Expansion of existing hydropower plants has some difficulties too, such as lowering of reservoir water level during the construction (suspension of generation during the construction) and economic validity, etc.

On the other hand, this Victoria expansion project has advantages, because intake facilities for expansion have been already constructed and it not necessary to lower reservoir water level during expansion works. In addition, the construction cost per kW of the expansion project is estimated at around US$1,000[1]. This cost is much lower than that of other candidate hydropower projects[2] ranging from US$2,700 to 3,200.

The maximum peak demand in 2008 was 1,922 MW. According to the daily load curve on the day recording the maximum demand, it is understood that about 570 MW of power source for the peak demand was necessary. The maximum power demand in 2016 is forecast as 3,222 MW by CEB. The required power sources for the peak demand are estimated at about 960 MW, under the condition that daily load curve in 2016 is similar to that in 2008. Hence new peak power sources of 390 MW (960MW-570MW) will be required to be arranged up to 2016. However, the power source for peak demand listed in the CEB' generation expansion plan shown in **4.2.1** is only Upper Kotmale (150 MW). If the Project with 228 MW is considered in the plan, the Project and Upper Kotmale will cover around 100% of this requirement. Therefore, the Project will contribute to coping with increase in the power demand.

The Project, therefore, has the high priority of development to meet the increasing peak demand and to effectively use the domestic renewable energy in the country.

Because large-scale thermal power plants to be commissioned after 2013 have not been committed, the commissioning year of some of them could be delayed for some reasons. In such a case, Victoria Hydropower Station could not be shifted from base/middle power sources to those for peak demand Therefore, capacity of new thermal power plants required to meet base power

[1] The construction cost per kW is calculated dividing the project cost estimated in 10.3.3 by the installed capacity (228MW) decided in the basic design.

[2] Source: Long Term generation Expansion Plan 2007-2021, April 2007, CEB

demand in 2016 when the Victoria expansion plant is scheduled to be completed is estimated based on the CEB's demand forecast mentioned in **4.1.4**. Consequently, it is concluded that base demand in 2016 will be satisfied when a thermal power plant with capacity of 300 MW is commissioned in addition to the Kerawalapitiya combined cycle plant (270 MW) and Puttalam coal-fired thermal plant Stage 1 (285 MW), if that retirement of the existing thermal power plants is not considered.

It is necessary, before commencement of Project implementation, to check the demand and supply plan on base power in the commissioning year of the Project and to use the Victoria Power Station for peak power sources.

Chapter 5 Meteorology and Hydrology

5.1 General

(1) Meteorology

The island of the Sri Lanka belongs to the tropical monsoon climate and is influenced by two monsoons. Seasons in the country consist of southwest monsoon, northeast monsoon, and two inter monsoon periods which are called intermonsoons. The southwest monsoon takes place from May to September pouring much rainfall in the southwest part of Sri Lanka. The northeast monsoon takes from December to February giving precipitation in central part and arid area of north and northeast part of Sri Lanka.

(2) Climate in the Mahaweli River Basin

The Mahaweli river is originating in the southwest part of the Central Highlands, flowing in the northeast part of Sri Lanka island, and effluent to the Trincomalee bay. The Mahaweli river basin is the largest in Sri Lanka with the total catchments area of 10,327 km^2 and river length of 335 km.

The climate in upstream part of the Mahaweli river basin is subject to southwest monsoon, and in the middle part of Central Highlands, where the Victoria Dam is located, is influenced by both monsoons. The downstream part of the basin is dry in southwest monsoon period and receives rainfall spontaneously in northeast monsoon period.

5.2 Meteorology and Discharge Measurement in the Project Area

(1) Rainfall Measurement

There are eight rainfall gauging stations nearby the project area operated by the Meteorological Department. At the hydropower stations of the Victoria and the Randenigala, CEB also measures the rainfall. Those rainfall records are collected during the Study. According to the record, the average annual rainfall at the Victoria dam is 1,375 mm. The rainfall pattern shows that the project area receives more rainfall in the northeast monsoon period than that of southwest period. Therefore, climate of the project is dominated by northeast monsoon.

(2) Discharge Measurement

The Polgolla diversion weir is located in 20 km upstream of the Victoria Dam, and is diverting the part of flow of the Mahaweli river into the Sudu river for irrigation purpose. The residual of water is released to the downstream and flows into the Victoria reservoir. The weir is owned and operated by MASL, and the release amount from the weir to downstream is monitored by MASL.

According to the MASL's records from 1985 to 2006, the average annual volume of inflow to the Polgolla weir is 1,949 MCM, annual average of 878 MCM is diverted to the Sudu river and the rest of 1,071 MCM is released to the Mahaweli river.

5.3 Water Resources Development of the Mahaweli River

(1) Water Resources Plan of the Mahaweli River

The master plan of the Mahaweli river was developed as the "Mahaweli Ganga Development Project" under UNDP/FAO assistantship in 1968. In 1977, the master plan was revised, and "Accelerated Mahaweli Development Programme" (AMDP) was issued. Based on the recommendations of AMDP, in early 1980s the Sri Lankan government undertook the construction of the four dams, which are Kotmale dam, Victoria dam, Randenigala dam, and Maduru Oya dam.

The operation rule of the Mahaweli river basin water resources facilities after completion of the above dams were determined in the study "Mahaweli Water Resources Management Project" in 1985 under Canadian International Development Agency (CIDA) assistantship. This study recommended the operation rule of principal reservoirs such as the Victoria reservoir in the Mahaweli river basin.

(2) Dam Safety and Water Resources Planning Project (DSWRPP)

DSWRPP is the project assisted by the World Bank and involves optimization of water resources of the Mahaweli river for preparation of "New Mahaweli Water Resources Development Plan" under MASL direction. The review of the water management of the Mahaweli river basin will include assessment of the operation policy for the diversion at the Polgolla weir. The results might give affects on the Project.

The water resources development plan of the Mahaweli river, "New Mahaweli Water Resources Development Plan", is scheduled to be finalized two years after the beginning of the study, which is expected to be in late April 2009, according to information as of late February 2009.

5.4 Discharge at Project Site

The inflow to the Victoria reservoir is a total of the release at Polgolla weir and inflow from the residual basin between the Polgolla weir and the Victoria dam. The inflow from the residual basin is not measured by any agency; however, it can be estimated by the difference between the total discharge from the Victoria dam and release at the Polgolla weir. According to the discharge data from 1985 to 2006, Polgolla weir released 1,071 MCM of water to downstream. The total annual discharge at the Victoria reservoir was 1,532 MCM. The difference between the Polgolla weir release and the total release at the Victoria dam is the inflow from the residual basin, which can be calculated to 461 MCM (= 1,532 MCM – 1,071 MCM).

5.5 Sedimentation

According to the dam operation office, the bottom outlet is opened before opening spillway gates during flood operation, and the discharging operation usually takes 2 to 3 hours, until the color of the water changes from brown to normal water color, and the bottom outlet is closed.

The sedimentation level was surveyed after the construction of the Victoria dam, and it was confirmed that sedimentation volume in 1995 (10 years after completion) was 1.1% of total reservoir volume. According to the dam operation office, sedimentation in the reservoir is not an issue for dam operation In 2005, the sedimentation of the large reservoirs including the Victoria was briefly examined. The report concluded that the sedimentation in the Victoria reservoir was not significant, and no additional countermeasures were needed. Therefore, the sedimentation will be relatively small compared with the reservoir capacity, thus it will not affect the Project.

Chapter 6 Optimization of the Development Plan

6.1 Comparison Study of Alternative Options

The expansion of the Victoria Hydropower Station is composed of a headrace tunnel, a surge tank, penstock(s), and a powerhouse. The water intake was already constructed for the purpose of future expansion of the hydropower facilities during the construction of the existing Victoria dam and hydropower station completed in 1985. One possible option of expansion plan is simply to place these components nearby the existing hydropower facilities, so as referred to as “Basic Option” in the Study. Besides this “Basic Option”, following additional two alternatives are envisaged by CEB and examined in the Study.

a) To install additional powerhouse further 2 km downstream of the existing powerhouse to increase an effective head (downstream option), and
b) To install pumped storage power station using the Victoria reservoir as an upper reservoir and the Randenigala reservoir as a lower reservoir (pumped storage option).

The general plan of the alternative options is shown in **Figure 6.1.2-1**.

The comparison study of alternative options aims to select the best option among the three candidates. Those alternative plans are compared with (1) economic aspect, (2) construction aspect, and (3) environmental impacts.

6.1.1 Peak Duration Hours

It is confirmed for the Study that the Victoria Hydropower Station after expansion will be operated for power source for peak demand.

The peak duration for the Hydropower Station after expansion is studied based on the daily and annual load curves. The peak duration is estimated at 3 hours through the year.

This duration pattern is the same as past duration curves and expected to continue in the future. Therefore the equivalent peak operation hours of the Victoria Hydropower Station are determined as 3 hours.

6.1.2 Scale of Expansion

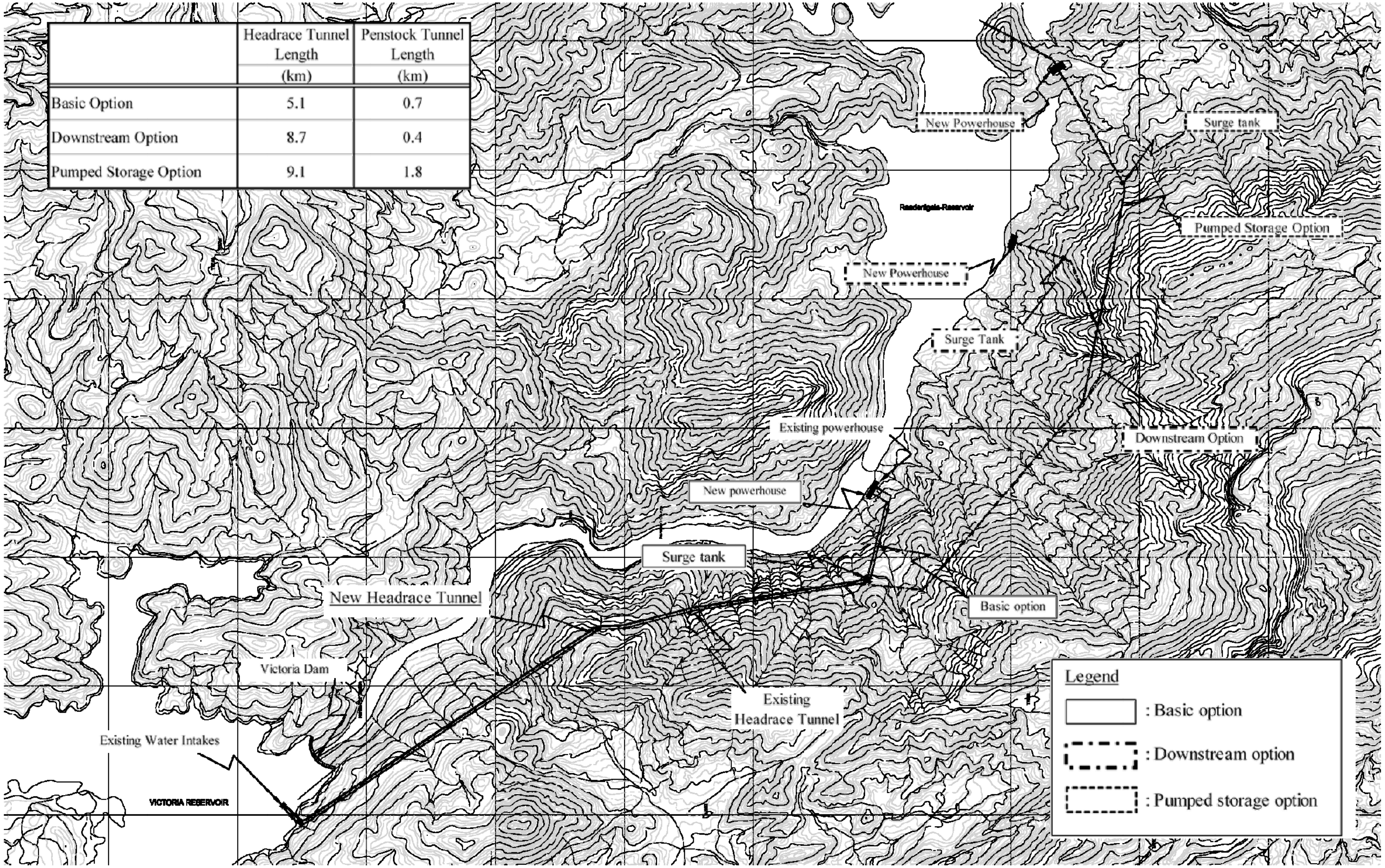
The available maximum plant discharge for the expansion plant is estimated, according to hydrological data, at 140 m^3/s which is the same maximum plant discharge as the existing power plant. The installed capacity with maximum plant discharge becomes 210 MW which is also the same as the existing plant. In the comparative study on the alternative options, 2-unit expansion (140 MW) is also examined in addition to the 3-unit expansion case (210 MW), assuming the unit capacity is the same as the existing plant of 70 MW.

The study scenario employed in this comparative study is shown in **Table 6.1.2-1**.

Table 6.1.2-1 Study Scenarios

		Basic Option		Downstream Option		Pumped Storage Option	
Number of units	(units)	3	2	3	2	3	2
Maximum plant discharge	(m^3/s)	140	93.4	140	93.4	140	93.4

	Headrace Tunnel Length (km)	Penstock Tunnel Length (km)
Basic Option	5.1	0.7
Downstream Option	8.7	0.4
Pumped Storage Option	9.1	1.8



SCALE 0 2km

Figure 6.1.2-1 General Plan of Alternative Options

6.1.3 Power Generation Simulation

The energy output is estimated by simulation using the discharge data into the Victoria reservoir from 1985 to 2006. Prior to conducting simulation, the operation rule of the Victoria reservoir is revised for the Victoria Hydropower Station with the expansion plant. The revised operation rule is used for estimating annual energy of each alternative option. The result of the calculation is shown in **Table 6.1.3-1**.

Table 6.1.3-1 Annual Energy and Power Output

	# of units	Expansion plant	Existing + Expansion plant					
		Installed Capacity	Annual Energy	Firm Energy*	Secondary Energy**	95% Dependable Capacity	Pump-up Energy	Net Annual Energy
		(MW)	(GWh)	(GWh)	(GWh)	(MW)	(GWh)	(GWh)
Basic Option	3	213	651	452	198	359		651
	2	140	651	381	271	336		651
Downstream Option	3	219	652	449	203	361		652
	2	143	652	378	275	333		652
Pumped Storage Option	3	198	729	445	284	396	-106	623
	2	128	711	343	368	310	-68	643

*Note: * "Firm energy" means the total of power generated during 3-hour peak duration.*
*** "Secondary energy" means the total of power generated in duration except 3-hour peak time*

As shown in the above table, the annual energy of the basic option and downstream option is almost the same. The annual energy of the pumped storage option apparently is larger energy than that of the other options. However, in consideration of energy for pump-up operation, the net annual energy of the pumped storage option is consequently smaller than that of others.

6.1.4 Benefit and Cost Analysis (B/C Analysis)

(1) Method

Three alternative options are compared by annualized economic benefit and cost of each option (B/C analysis). Economic benefit is composed of capacity and energy benefits. The capacity benefit is costs comprised of capital cost (construction cost) and fixed O&M cost of the alternative gas turbine plant which has equivalent generation capacity. The energy benefit consists of the fuel cost and variable O&M cost of the alternative gas turbine (in peak duration) and coal-fired thermal plant (in off-peak duration).

The cost of the project on each option is composed of construction cost, environmental mitigation cost, pump-up cost for pumped storage option, and cost due to drawdown of the Randenigala reservoir water level for downstream and pumped storage options.

(2) Unit Construction Cost

Unit construction cost is a cost per installed capacity of the expansion plant. The unit construction cost of each alternative option is calculated as below.

Table 6.1.4-1 Unit Construction Cost of Alternative Options

Item	Unit	Basic Option		Downstream Option		Pumped Storage Option	
		3 units	2 units	3 units	2 units	3 units	2 units
Unit Construction Cost	US$/kW	808	962	974	1,167	1,699	2,063

(3) Result of B/C Analysis

The ratio of the benefit to the cost (B/C) for all options is shown in **Table 6.1.4-2**.

Table 6.1.4-2 Summary of B/C Analysis

Item	Unit	Basic Option		Downstream Option		Pumped Storage Option	
		3 units	2 units	3 units	2 units	3 units	2 units
Installed capacity	MW	213	140	219	143	198	128
Benefit	Mill. US$/year	40.9	30.1	40.6	29.6	47.4	26.9
Cost	Mill. US$/year	22.3	17.5	28.5	22.5	53.1	41.5
B / C		1.83	1.72	1.43	1.32	0.89	0.65

Consequently, the basic option with 3 units (210 MW) is the most economical option with respect to the B/C analysis.

6.1.5 Study Using WASP-IV

Study Team examined analytical models of the three alternative options and provided the input data of WASP-IV (power development planning tool) of each option with CEB. Study Team and CEB analyzed three alternative options with WASP-IV.

The analysis of WASP resulted in that the basic option with 3 units has the least total cost (capital cost of new power sources and O&M cost of the power stations) for the power system operation of CEB for the examination period (2008-2027) of the three options.

6.1.6 Result of Comparative Study

As described in **Section 6.1.5**, WASP analysis concluded that 3-unit expansion of the basic option is selected as the least total cost option. In terms of economic aspect, the result of comparative study on three alternatives shows that the 3-unit expansion of basic option is the optimum option.

The Study Team concludes that the basic option with 3 units is the optimal option from the viewpoint of economic, environmental and construction aspects (refer to Section **8.2** for the comparison from environmental impact aspect).

6.2 Optimization of Expansion Plan

According to the result of the comparative study on the alternative options, the basic option with 3 units with the total capacity of 213 MW is selected as the optimal option among the three alternatives. In this section, the following details of the selected expansion plan are examined.

(1) Unit capacity and number of units,
(2) Normal intake water level, and
(3) Priority of operation for existing and expansion plant.

6.2.1 Number of Units and Unit Capacity

In the comparative study on the alternative options, the unit capacity was tentatively fixed to 70 MW. The optimum number of unit is studied by fixing the total capacity to 210 MW class. The number of units and unit capacity examined in the Study is as follows.

(1) 70 MW class × 3 units
(2) 105 MW class × 2 units
(3) 210 MW class × 1 unit

The Study Team examined the unit capacity of expansion plant in terms of system frequency deviation under loss of the unit, maintenance activities, constraints of transportation for heavy equipment parts, and economic validity.

The study results in that the constraint of system frequency deviation does not allow installing 210 MW unit capacity, and the 2-unit option is selected in terms of transportation, maintenance and economic aspect.

6.2.2 Normal Intake Water Level

In the comparative study of alternative options, the normal intake water level was empirically set at EL. 415 m, by one third of the available drawdown (FSL – MOL of the reservoir) lower than FSL of the Victoria reservoir. In this optimization of the expansion plan, the normal intake water level is determined by sensitivity analysis applying the normal intake water level to EL.415 m, EL. 425 m, EL. 430 m, EL. 435 m, and EL. 438 m.

The result of the study shows that the normal intake water level of EL. 430 m is economically optimum for the expansion units. Therefore, the normal intake water level of EL.430 m is applied to expansion plant.

6.2.3 Operation Priority between the Existing and Expansion Units

Study Team examines operation rule after expansion by prioritizing the use of existing and expansion units. Three ways of the operation are considered for the use of existing and expansion plant as follows;

Rule 1 : Using both existing and expansion units in the same way,
Rule 2 : Using existing units first, then the expansion units, and

Rule 3 : Using expansion units first, then the existing units.

The above three rules are compared by the economic analysis. Economic analysis shows that "Rule 1" provides the largest benefit. Therefore, it is recommended to operate the both alike.

6.2.4 Optimal Expansion Plan

The optimal expansion plan is determined, in terms of economical view points, for number of units, the normal intake water level, and operation priority of existing and expansion units.

The results are summarized below;

Number of units	: 2 units
Normal intake water level	: EL. 430 m
Operation rule of existing and expansion units	: Same operation for existing and expansion plants.

6.2.5 Maximum Possible Power Generation

In the comparative study on alternative options and optimization of expansion plant, spillout and sand-flushing discharges were deducted from inflow for power generation simulation, since those discharges were not used for hydropower generation. In this section, the spillout discharge is taken into account as available water for hydropower generation.

Simulation on the power generation resulted in that hydropower generation with the expansion plant will increase energy from 635 GWh/year to 716 GWh/year if the spillout discharge is available for hydropower generation.

Chapter 7 Geology

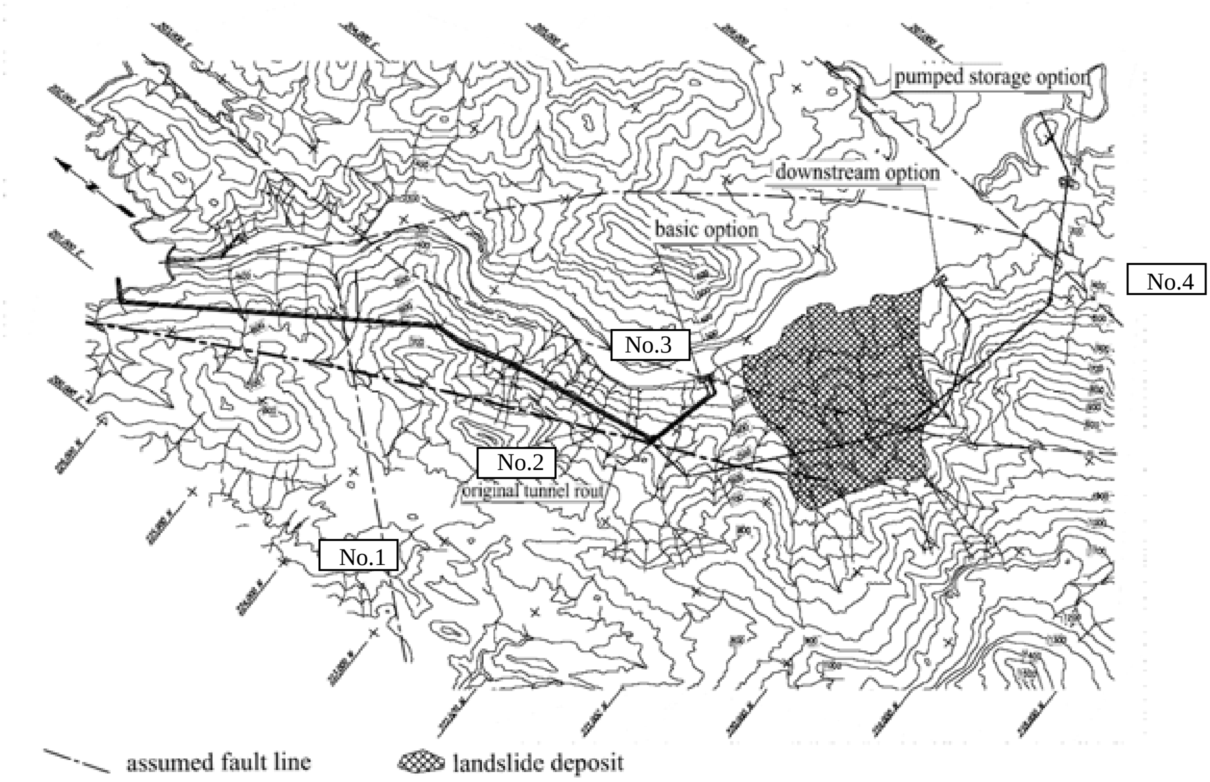
7.1 Outline of the Geology of the Project Area

The basement rock of Sri Lanka is divided into three tectonic provinces: The Highland-Complex lies longitudinally in the middle of the island including the Central Highlands, The Vijayan-Complex (eastern Vijayan-Complex) lies in the eastern part of the island, and the Wanni-Complex (western Vijayan-Complex) lies in the western part of the island.

The Victoria project site is located in the Highland-Complex province, and the basement rock is composed of high-grade metamorphic rocks.

7.2 Outline of the Site Geology of the Three Alternative Options

Figure 7.2-1 shows the remarkable geological phenomena such as five faults referred to the 1:100,000 geologic map issued by the Geological Survey and Mines Bureau of Sri Lanka (GSMB), and landslide deposits identified by the site reconnaissance carried out by Study Team. The No.2 fault is fatal and the worst among them. The rock condition of the No.2 fault is so poor that the existing tunnel alignment was revised in order to avoid it during construction. Attention should be paid to the basement rock under the landslide deposit, because its weathered zone is deep and rock cover of tunnel alignment is thin. The basic option is considered to be in the most favorable location, because it is the only one option that avoids encountering both No.2 fault and the landslide deposits.



Source: fault: refer to Sri Lanka 1:10,000 Geology, Geological Survey and Mines Bureau of Sri Lanka
Landslide deposit: Based on the site reconnaissance during this study

Figure 7.2-1 Main Geological Structure of Project Area

7.3 Site Geology of the Basic Option

As facilities of the basic option are to be located adjacent to the existing facilities, the rock conditions will be very similar to those of the existing facilities. Therefore, geotechnical evaluation on the new facilities was carried out based on the documents of construction works of the existing facilities such as the geotechnical report on the tunnel, the construction report on the powerhouse, and many drawings (geological plans, geological sections, 12 sheets of geotechnical records of the tunnel, support works, grouting works, and so on).

7.3.1 Waterway

(1) Topography

The ridgeline of the right bank is 400 to 500 m high from the river bed. The inclination of the slope where the exiting tunnel is located is about 30 to 40 degrees. The rock cover of the new tunnel is about 150 m or more in the most part. The minimum rock cover portion is around [3]Ch. 2,000 m under a tributary valley, where the rock cover is slightly less than 100 m.

[3] Ch. 2000 m" means the horizontal distance at the point of 2000m from the upstream portal along the tunnel alignment.

(2) Geology

The basement rock of the waterway alignment is composed of high-grade metamorphic rocks such as Gneiss (Garnetiferous-Quartz-Gneiss, Quartz-Biotite-Gneiss, Biotite-Gneiss), Guranulite, Quartzite, Crystalline Limestone (Marble). The syncline lies along the riverbed and the foliation dips downward to the riverbed from the both banks. Basically, the dip varies 15° at the riverside to 40° at the upper slope of the right bank. The highly weathered zone assumed to be muddy or sandy distributes about 1 m in depth from the ground surface, and under it another zone with 2 to 10 m deep is moderately weathered zone which is assumed to be loose blocks of rocks. Below them there should be a mixture zone of fresh rock and slightly weathered rock with oxidized joint faces. The ratio of slightly weathered rock becomes smaller when it comes deeper.

(3) Geotechnical Evaluation

The rock condition is expected to be basically good, because every high-grade metamorphic rock is essentially hard, the joints are widely spaced and any deep weathering zone or geothermal alteration zone have not been recognized. However some weak rock zones are recognized and have something to do with the peculiarities of each rock described as follows: i) Gneiss, Granulite, and Quartzite are occasionally highly jointed along the foliation plane and the orientation which is perpendicular to the foliation. ii) Both biotite layers in the Gneiss and mica layers in the Quartzite sometimes perform as slippery planes and tend to cause the instability of rocks. iii) Crystalline Limestone is expected to be rarely jointed and basically in good condition. However, thin Crystalline Limestone layers which included in other kind of rocks are sometimes got weathered selectively and tends to causes the instability of rocks.

The basement rock is classified into four rock types, ranging from the best rock Type I to the worst rock Type IV, based on the rock mass classification used during the previous construction works. The Type IV corresponds to the condition of No.2 fault zone so the Type IV will not appear in the new tunnel.

1) Existing Tunnel

Records of construction works such as rock name, rock type, groundwater inflow, support, and grouting are shown in **Figure 7.3.1-1**. The rock condition is considered to be good, because the sum of Type I and Type II rocks accounts for 97% of tunnel and the rest is Type III rock. The Types II and Type III rocks are separated and tagged as “poor zone” which is also shown in the profile.

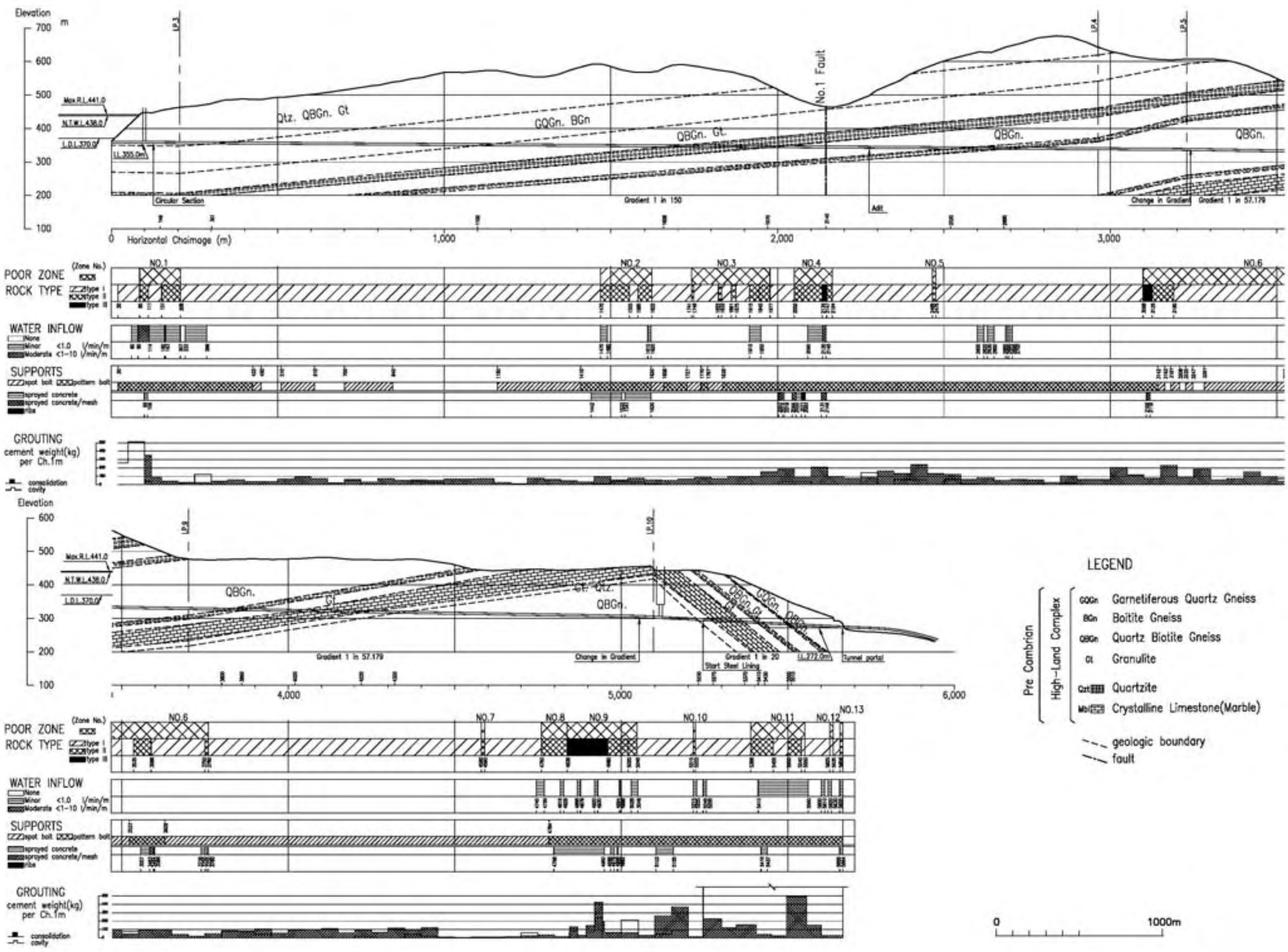


Figure 7.3.1-1 Geologic Profile of Existing Tunnel

2) New Tunnel

The assumed sections of rock name, poor zone, rock type, and groundwater inflow are shown in **Figure 7.3.1-2**. Minor groundwater inflows may occur in poor zones, quartzite zones, and the weathered zone at the portal. And major groundwater inflows might occur in weathered zone at the portal, No.1 fault zone, and the Crystalline Limestone zones where unpredictable cavities might exist because of its soluble nature.

When the tunnel excavation reaches to the poor zones shown in **Table 7.3.1-1**, the tunnel wall would be stabilized with the adequate supports pattern of its rock type. Probe drillings and pre-grouting to the major groundwater inflows during the construction stage would decrease the hydrological impacts caused by the new tunnel excavation.

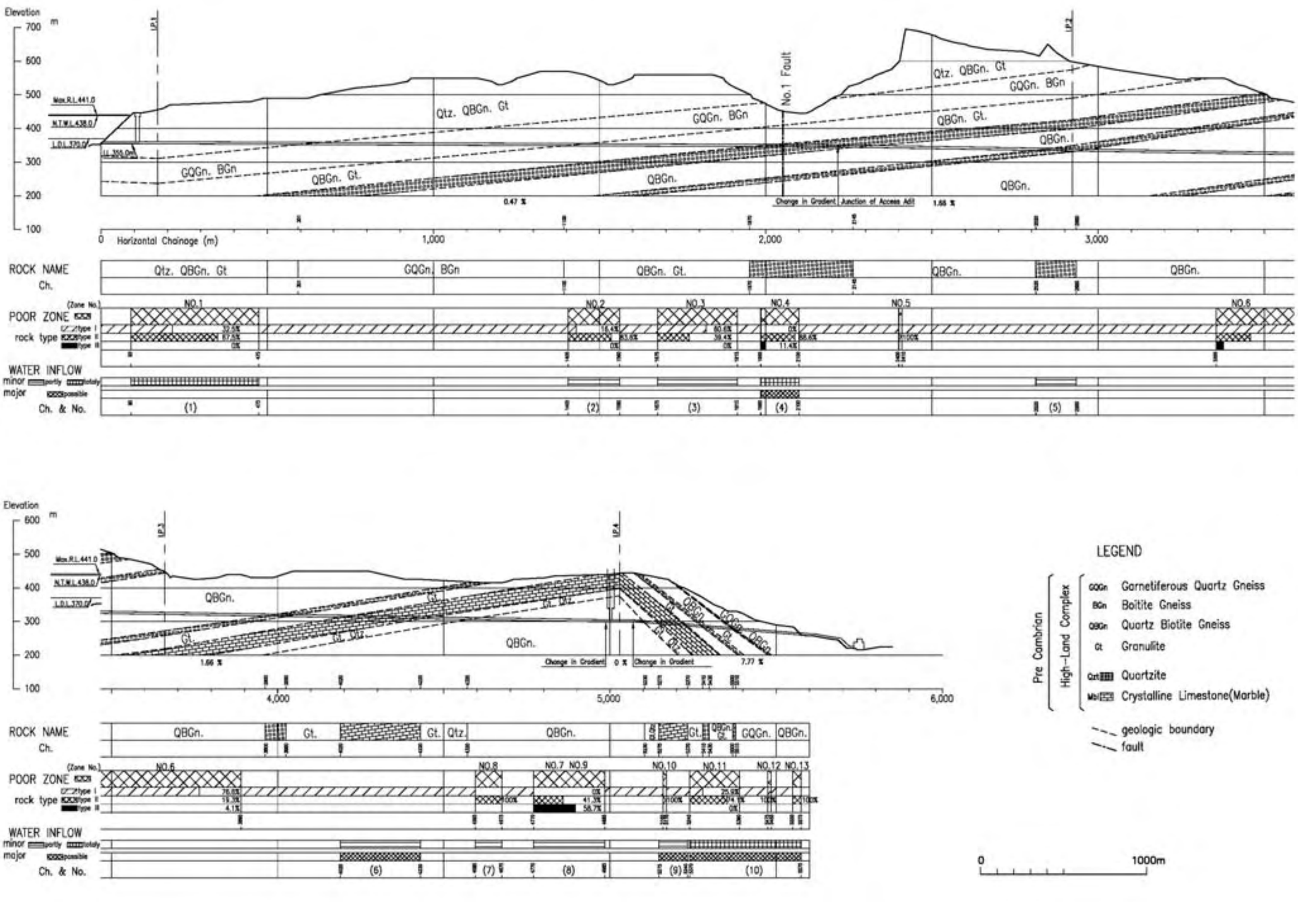


Figure 7.3.1-2 Geologic Profile of New Tunnel

Table 7.3.1-1
Assumed Sections where Poor Zones will be Encountered along the New Tunnel

Zone No.	Assumed condition											
	Ch. (m) new tunnel	Width(m)	Rock Type						Geology	Orientation	Geological condition	Support items
			I		II		III					
			%	m	%	m	%	m				
1	90 - 475	385	32.5	125	67.5	260	0.0	0	Granulite /Quartzite	pararell to the foliation	There will be some jointed rock zones associated with smooth beddings and merely minor cavitated zones.	3m pattern bolts
2	1,405 - 1,560	155	16.4	25	83.6	130	0.0	0	Granulite	perpendicular to the foliation	There will be some jointed rock zones associated with smooth beddings, slickensided steep joints and minor faults.	3m pattern bolts partly 50mm shotcrete
3	1,675 - 1,915	240	60.6	145	39.4	95	0.0	0	Granulite	perpendicular to the foliation	There will be some jointed rock zones associated with slickensided steep joints and minor faults.	3m pattern bolts
4	1,985 - 2,100	115	0.0	0	88.6	102	11.4	13	Quartzite	perpendicular to the foliation	A jointed rock zone associated with a series of minor faults and slickensided steep joints.	3m pattern bolts partly 50-100mm shotcrete partly ribs
5	2,400 - 2,410	10	0.0	0	100.0	10	0.0	0	Gneiss	perpendicular to the foliation	A jointed rock zone associated with smooth beddings and steep joints.	3m pattern bolts
6	3,355 - 3,890	535	76.6	410	19.3	103	4.1	22	Gneiss	pararell to the foliation	There will be some jointed rock zones associated with shattered rock, sheared beddings and weathered micaceous Limestone layers.	3m pattern bolts partly 50mm shotcrete partly 100mm shotcrete with weld mesh
8	4,595 - 4,675	80	0.0	0	100.0	80	0.0	0	Gneiss	diagonally across the foliation	A jointed rock zone associated with minor faults, steep slickensided joints and smooth beddings.	3m pattern bolts 4m long tensioned rock bolts 100mm shotcrete with weld mesh
7,9	4,770 - 4,985	215	0.0	0	41.3	89	58.7	126	Gneiss	perpendicular to the foliation	A shattered zone associated with a series of minor faults and steep slickensided joints	4m pattern bolts partly 50-100mm shotcrete
10	5,160 - 5,170	10	0.0	0	100.0	10	0.0	0	Gneiss	perpendicular to the foliation	A minor fault	3m pattern bolts
11	5,240 - 5,390	150	25.9	39	74.1	111	0.0	0	Granulite Quartzite	pararell to the foliation	There will be some jointed rock zones associated with a minor sheared zone and micacious Limestone layers.	3m pattern bolts partly 50mm shotcrete with weld mesh
12	5,475 - 5,485	10	100.0	10	0.0	0	0.0	0	Gneiss	pararell to the foliation	A broken and sheared zone associated with clay, which will contribut to the formation of weadges and blocks. Much groundwater inflow may appear.	3m pattern bolts partly 4m long tensioned rock bolts partly 50mm shotcrete with weld mesh partly ribs
13	5,550 - 5,575	25	0.0	0	100.0	25	0.0	0	Gneiss	pararell to the slope	A weathered and jointed rock zone associated with smooth beddings and slickensided steep joints.	3m pattern bolts 50mm shotcrete ribs

3) Surge Tank

The geologic profiles of the new surge tank are shown in **Figure 7.3.1-3**. The rock condition is expected to be as good as that of existing surge tank. Core drillings are recommended to be carried out during the detailed design stage in order to certify the boundaries of geology and weathered zones.

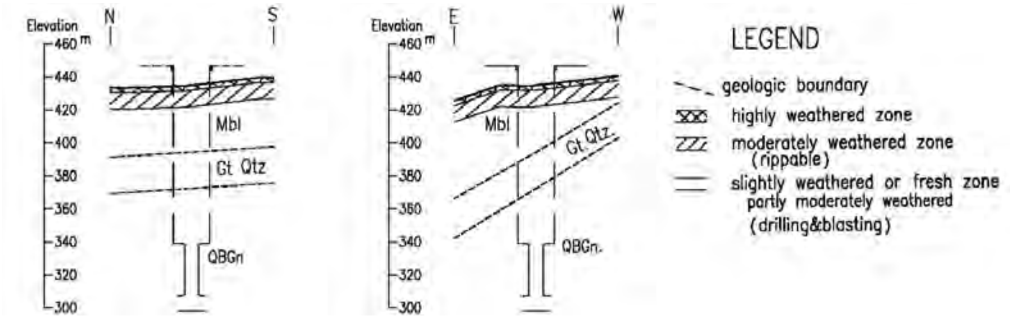


Figure 7.3.1-3 Geologic profile of New Surge Tank

4) Surface Type Penstock

The geologic profiles of the new penstock are shown in **Figure 7.3.1-4**. The basement rock of the slope is mainly composed of Gneiss (Garnetiferous-Quartz-Gneiss), of which foliation is nearly parallel to the slope inclination, and the biotite layers tend to become slippery planes when they are in the weathered zone. Due to such biotite layers and a small fault, a slip of about 100 m^3 of material occurred during the previous construction. It is necessary to pay attention to the existence of instable blocks in the weathered zone, and to install the adequate rock bolts when it appears during construction stage. Core drillings at the anchors are recommended to be carried out during the detailed design stage in order to certify the boundaries of weathered zones.

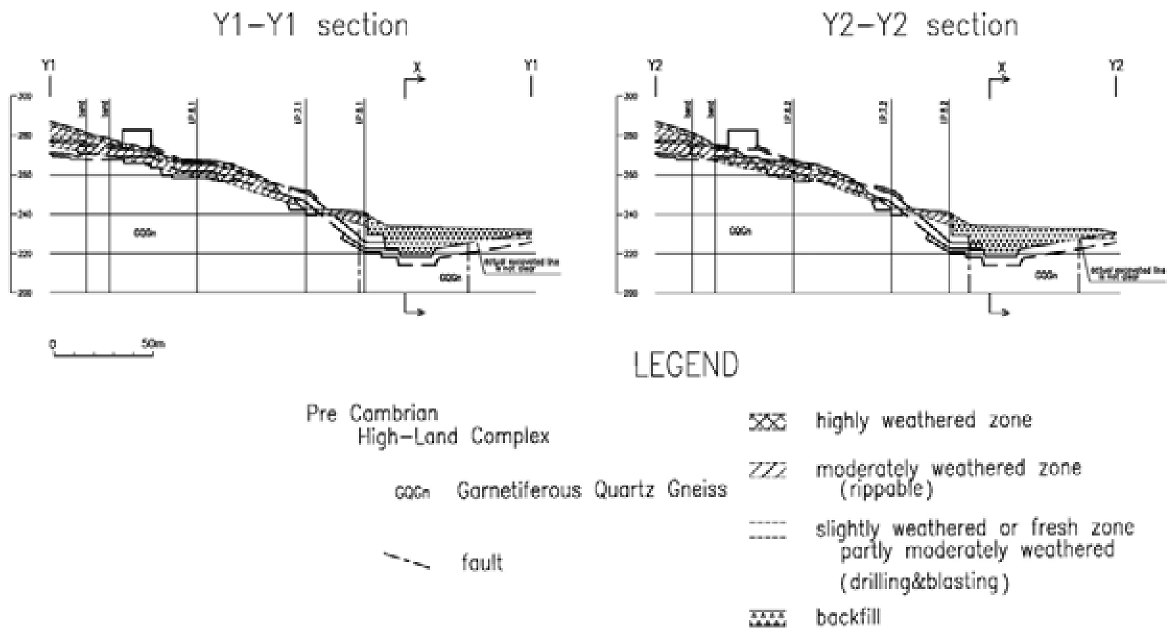


Figure 7.3.1-4 Geologic Profile of Penstock

7.3.2 Powerhouse

The geologic section of powerhouse is shown in **Figure 7.3.2-1**. The basement rock is composed of Gneiss (Garnetiferous-Quartz-Gneiss, Quartz-Biotite-Gneiss). The weathered zone was already removed, and the fresh rock and slightly weathered rock are exposed on the foundation surface. There are two parallel faults striking NNW-SSE. The western fault is associated with 1 to 2 m wide shear zone, and the eastern fault is associated with 5 m wide shear zone. The strict positions of them are not clear, but substitute concrete for the sheared zone would keep the foundation bearing. Attentions will have to be paid to excavation works, because the gently dipping foliation beds and steep joints tend to form isolated blocks which might cause overbreaks on the horizontal foundation surfaces.

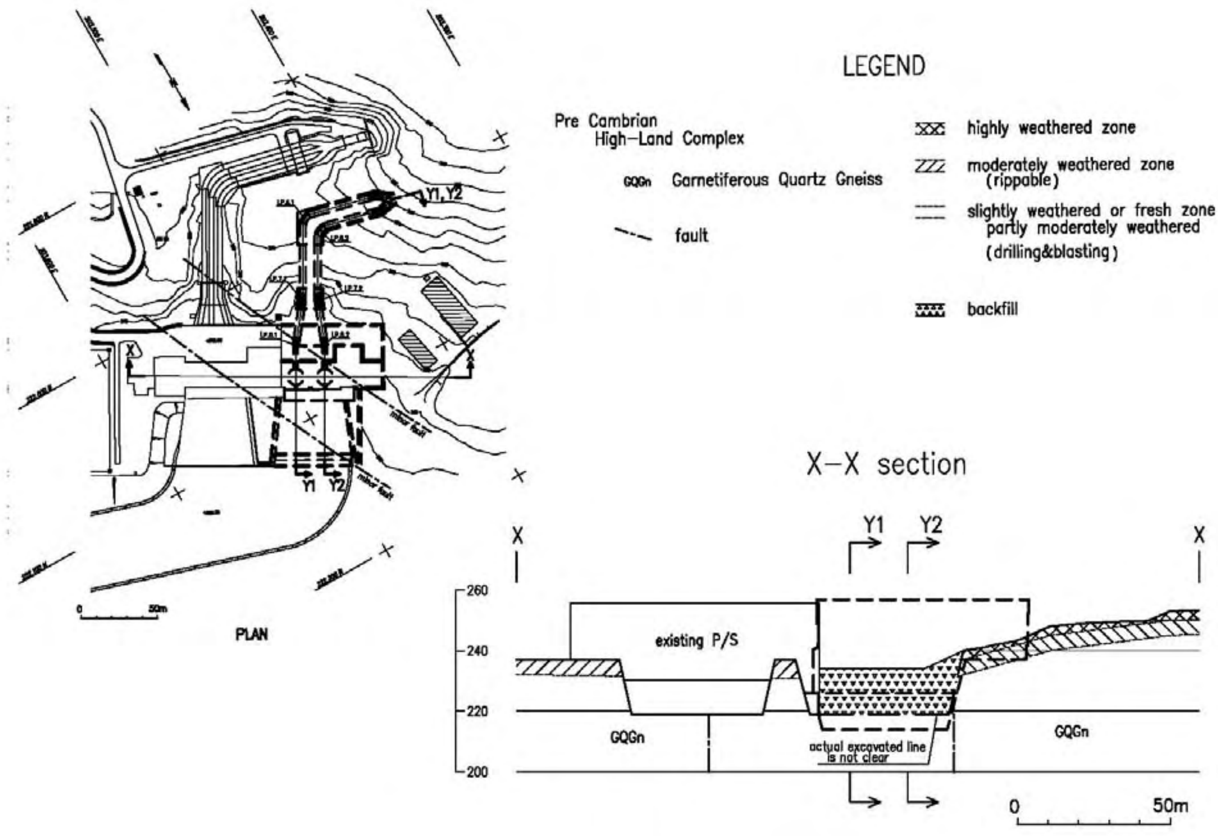


Figure 7.3.2-1 Geologic Section of Powerhouse

7.4 Construction Material

The existing quarry site is located 1 km downstream of the dam, where the coarse and fine aggregates were produced during the previous construction. But the quarry site is omitted in order to prevent the environmental impact. As mentioned in **Chapter 10**, fresh rock obtained from the tunnel excavation is considered for the aggregates instead. The river sand at the tributary valley located 5 km upstream from the CEB's tunnel office has a possibility for use as the fine aggregates. However it was revealed that the suitable sediments do not distribute in the Mahaweli river, Victoria reservoir, and the upstream part of the Randenigala reservoir.

Chapter 8 Environmental Impact Survey

8.1 Laws, Guidelines, and Procedures of Sri Lanka

The Project follows EIA procedure based on the National Environmental (Procedure for Approval of Projects) Regulations No. 1 of 1993, as contained in gazette extraordinary No. 772/22 of 24th June 1993. Study Team supported CEB from time after a scoping meeting up to time immediately before EIA Report reviewing by PAA.

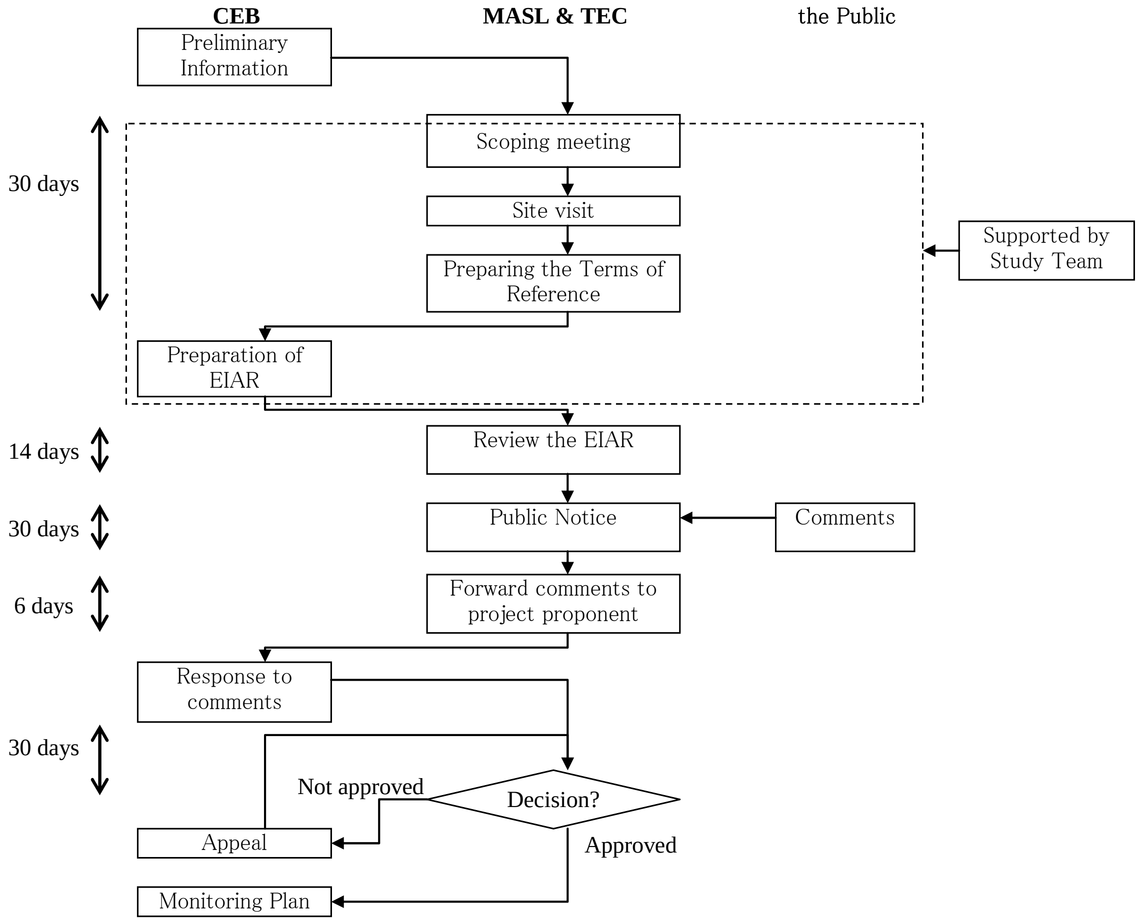


Figure 8.1-1 EIA Procedure

8.2 Survey on Environmental and Social Considerations in Preliminary Study of Alternative Options

8.2.1 Compared Options

The compared options are the three options, the basic option, downstream option, and pumped storage option, and the ground plan of each option is shown in **Figure 8.2.1-1**.

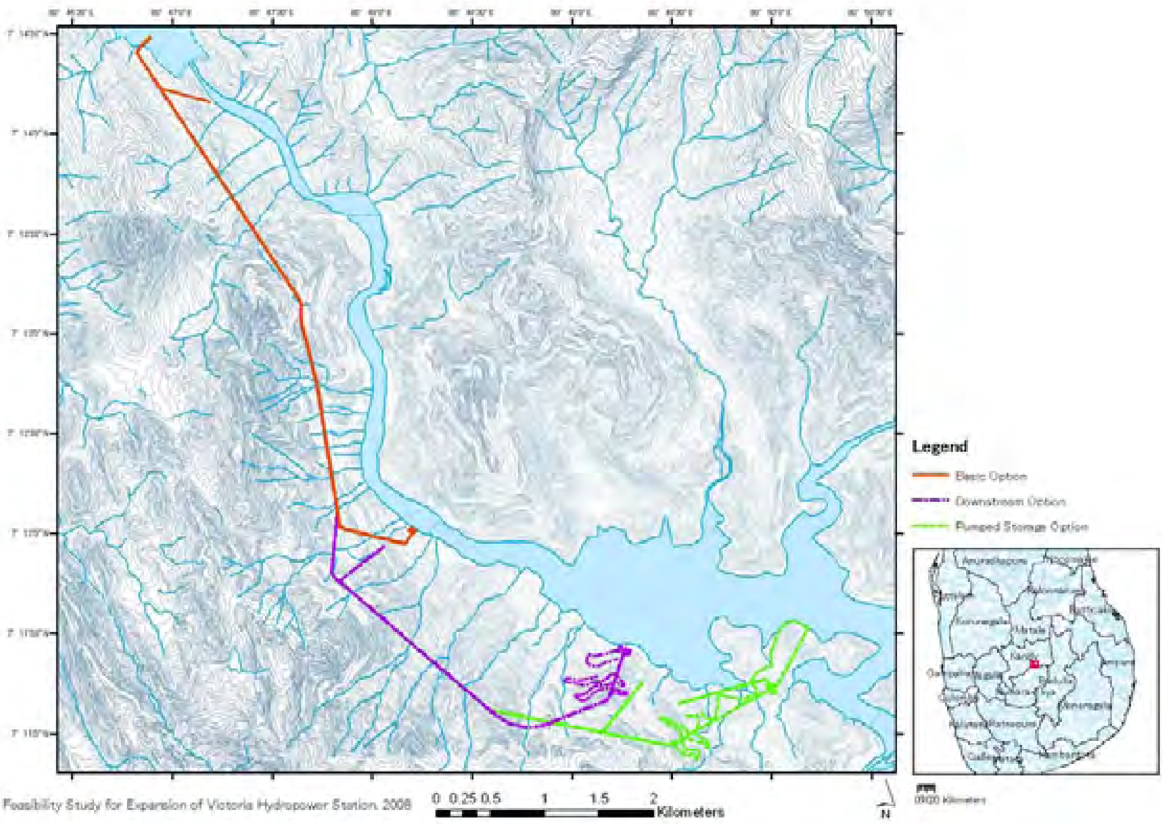


Figure 8.2.1-1 Options (Ground Plan)

8.2.2 Impact Assessment

With all the items compared, the basic option is preferable to the other options in both the economic and environmental aspects. **Table 8.2.2-1** shows a summary of the comparison.

Table 8.2.2-1 Comparative Table for Three Options

	Items	Basic Option	Downstream Option	Pumped Storage Option
Economic aspect	Effective head (m)	** 170	*** 175	* 165
	Annual energy	*** 1.0	*** 1.0	** 0.9
	Construction period	*** 5.5 years	** 6.0 years	* 6.5 years
	Construction cost	*** 1.0	** 1.3	* 1.8
	Reduction in energy during construction	*** 0	** -11%	* -34%
Environmental aspect	Forest cutting area by access roads (m^2)	*** 0 m^2	** 16,385 m^2	* 20,677 m^2
	Impact on sanctuary (ha)	*** 804.9 ha	** 7,262.0 ha	* 7,319.0 ha
	Length of new access road (m)	*** 0 m	** 2,823 m	* 3,722 m

	Items	Basic Option	Downstream Option	Pumped Storage Option
	Indirect impact on land use (ha)	*** Forest: 210 Scrub: 245 Chena[4]: 114 Homestead: 10 Paddy: 15	** Forest: 381 Scrub: 261 Chena: 202 Homestead: 68 Paddy: 74	* Forest: 486 Scrub: 291 Chena: 202 Homestead: 116 Paddy: 74
Social aspect	Increase in jobs	*	**	***
	Decrease of water level of Randenigala reservoir during construction	*** 0 m	** 23 m, 1 years	* 25 m, 1.5 years
	Impact on the existing facilities	*** 57 buildings	** 111 buildings	* 174 buildings

****: Best*   ***: Second best*   **: Worst*

8.3 Survey on Environmental and Social Considerations for Optimal Option

8.3.1 Impact Assessment and Mitigation

Environmental impacts are assessed for the selected basic option. 12 main negative impacts are assessed, and mitigation measures for each impact are planned respectively.

(1) Provision of Water Supply to the Affected Families for the Loss of Groundwater

57 houses consisting of 241 people in the impact area would possibly be in a target for water supply. Since there is no natural water source to establish a piped-water system in these two villages this impact has to be mitigated by supplying water with water tank trucks as required. The water supply is only during construction, because the drawing down period is estimated only during construction. The daily requirement of water in the rural sector has been estimated at 100 liters/day per person (National Water Supply and Drainage Board, 2006). Thus the total volume of water that would have to be supplied annually is 8,796.5 m^3 if all the wells dry up and no rain water is available in the area during the construction period. This would require roughly 8 water tank trucks (with a 3 m^3 in capacity) a day.

(2) Cash Compensation for the Loss of Agricultural Production

The total maximum value of the cash compensation for the loss of agricultural production is Rs.28.9 million including Rs.22.3 million for Chena, Rs.5.1 million for Homestead, and Rs.1.5 million for Paddy (See **Table 8.3.1-1**).

[4] One of the swidden agriculture styles in Sri Lanka

Table 8.3.1-1 Estimated Compensation Cost for the Loss of Agricultural Production

Type of Agriculture	Economic loss (Rs./year)	Year	Compensation cost (Rs.)	Remarks
Paddy	373,700	4	1,494,800	Table 4-8, EIAR
Chena	5,576,200	4	22,304,800	Table 4-9, EIAR
Home Gardens	1,272,530	4	5,090,120	Table 4-10, EIAR
Total			**28,889,720**	

(3) Mitigation for Vibration Impacts

The construction of the Project carries out underground and open-air works near the existing Victoria dam, intake for expansion, existing waterway and powerhouse. The maximum vibration limit was set for blasting work for the construction works. (See **9.2**) The amount of explosive must be controlled in order to keep under the acceptable value. The contractor should carry out several times of trial blasting, each time loading different amount of explosives, in the new access adit to confirm appropriate blasting method with the maximum allowable blasting vibration, and measure the velocity of vibration with vibrographs at the intake gate shaft and/or in the dam inspection galleries. The contractors should strictly watch the blasting method, amount of explosives, etc., with the trial blasting. Vibration due to the blasting during construction period should be measured on the existing structures and/or rock surfaces with the vibrographs to confirm safety of the existing structures.

The impact on the houses would be small in consideration of distances between houses and blasting points if the amount of the explosive of the blasting does not affect the existing buildings. The excavation of the surge tank in the Hakurutare GN division will be done only in daytime (around 10 hours) in order to prevent the villagers from receiving the noise and vibration impact of blasting on during night time.

(4) Control Spillage/Treating the Tunnel Discharge

Tunnel discharge will contain high amounts of suspended particles. In addition it could also contain nitrates from explosive materials, oil and grease from machinery, and other impurities based on the mineral composition of the excavated materials. All tunnel waste water must be treated for suspended solid removal, oil and grease removal, nitrogen compound removal and any other substance that is in excess of the prevailing discharge standards. The use of a grease trap followed by a settling/lagooning tank should be adequate to treat this waste water up to the required levels.

(5) Strict Safety Measures to Prevent Work Accidents

The local workers should be educated and trained to follow safety measures. Proper safety equipment should be made available to the construction crew and visitors. Notices displaying the safety warnings and precautions must be placed at all work fronts. The workforce and the visitors should be compelled to follow the safety guidelines and regulations strictly. A stock of basic first aid medicine with trained personnel should be available around the clock. An ambulance also should be made available. The Project Proponent should maintain comprehensive daily records on the safety of its workers at all construction sites.

(6) Environmental Restoration Program to Prevent Soil Erosion

The rehabilitation of forest cover at the dumping sites consists of three components; soil conservation, rehabilitation and replanting, and maintenance. The total area of the dumping sites is estimated at 15.66 ha.

(7) Mitigation for Noise Impact

The PP should request the contractor not to use old machinery and to maintain them in excellent working conditions so that they generate only the minimum noise. This is especially applicable to the heavy vehicles transporting sand and muck.

(8) Mitigation for Groundwater Pollution

All waste waters must be properly treated (to comply with the existing discharge standards) before releasing it into the surrounding. In addition all toilet waste disposals must be guaranteed as safe for area groundwater. All toilet waste water from camp and construction sites must be separated and treated on sites by using conventional septic tank systems. Hazardous wastes such as vehicle maintenance waste should not be dumped on open ground and must be collected separately and disposed of in an appropriate manner.

(9) Awareness Programs for the Workers

A general awareness program for the workers should be conducted by professionally qualified experts on socially communicable diseases on a regular basis during the construction period and also on the need to respect the sociocultural environment of the local communities.

(10) Repairing of the Damaged Road

The total length of the existing road that will be used during construction is estimated at 18 km. In total, a 10-ton damp truck will make 115,500 trips during the construction period estimated to last 52 months. However, it has not been estimated how much damage that could cause taking into consideration the weight of the vehicle and number of trips. Therefore, the RDA cost estimation for patching damaged roads were used in calculating the mitigation cost. Either the Project itself can repair the roads or enter into an agreement with the RDA to effectively repair the road on a continuous basis.

(11) Installing Flash Lights and CCTV Cameras to Monitor the Migration of Elephants

To ensure that impacts on elephant migration are mitigated, the first requirement is to build a sufficient database on the actual migration pattern of elephants across the stream downstream of the proposed powerhouse. For this purpose, as a preliminary measure, eight CCTV (Closed

Circuit Television) cameras will be installed at an early stage of the construction, if possible one year before the commencement of the construction works, at reasonable intervals on the right bank of the channel to observe the presence of elephants on the stretch of the river bed concerned. The ethological specialists including those of DWLC will be appointed for elephant survey and analysis. If the elephants' presence is confirmed during the observation in the pre-construction period, it is suggested controlling the blasting timing in consideration of the activity time and area of the elephants during the construction period. And installation of flash lights is also suggested in the operation stage. The flash lights will be installed in the river bed and flash 15 minutes before the commencement of plant operation to warn the elephants. Eight lamps will be installed at 8 defined cross sections downstream of the powerhouse. The mitigation measures for elephants will be continually revised based on the survey and analysis results.

(12) Compensation for the Loss of Private Land at the Dumping Site at Kohombagana

About 6.2 ha of land at the Kohombagana candidate muck dumping site is owned privately but the land is now abandoned and is overgrown with vegetation. Although there is no market for land in this area due to the declaration of the VRRS, it is important that the rightful owners receive cash compensation for the land. After several discussions with the villagers and officials, it is proposed that they will be compensated with a hypothetical value of Rs.100,000.00 per acre.

8.3.2 Monitoring Plan

Monitoring committee consists of CEB, MASL, DWLC, etc. is planned. The proposed monitoring plan is shown in **Table 8.3.2-1**.

Table 8.3.2-1 Monitoring Program

Impact	Nature of Impact	Mitigation Measure	Monitoring					
			Parameter	Locations	Method	Frequency	Duration	Responsibility
(1) Temporary lowering of ground water affecting domestic uses	57 house holds will be affected.	Provision of mobile water supply to the affected families	The number of affected houses getting the supply	Houses	Enumeration of changing ground water level	Weekly	One year in pre-constructio n stage if possible, construction period and additional one year	Monitoring committee/ Preconstructio n ground and surface water levels and quality survey is recommended.
(2) Temporary reduction in agricultural production (paddy, home garden) to lowering of ground water	139.2 ha (Rice field and vegetable field)	Cash compensation for the loss	The affected agricultural plots	Plots	Enumeration	Every four months	Construction period and additional six months	Monitoring Committee
(3) Impact on the integrity of the existing tunnel and other structures	Blasting is controlled by the use of appropriate specific charges in the blasting rounds to limit peak particle velocity not exceeding 2cm/sec.	Use of modern and safe technology Recording actual status of the existing structures in the pre-construction stage is recommended.	Blasting vibration	Dam/Power House/Other affected places and houses (Tunnel will not be directly monitored as it is in operation)	Continuous monitoring using vibrometers and spot checks	Continuous/ when required	Construction periodx	MASL and CEB
(3b) Impact on the integrity of the existing houses	Blasting is controlled by the use of appropriate specific charges in the blasting mentioned in (3) above.	Use of modern and safe technology Pre-construction structural distress survey (crack survey) is recommended	Use of machines and methods	Sites of Operations	Observation	Monthly	Construction period	Monitoring Committee

Impact	Nature of Impact	Mitigation Measure	Monitoring					
			Parameter	Locations	Method	Frequency	Duration	Responsibility
(4) Pollution of surface water from tunnel discharge and at tunnel muck sites	10 locations are estimated as possible impact area. But no houses will be affected.	Control spillage/Treating the tunnel discharge through oil traps	Water Quality parameters and the proper functioning of the treatment	Discharge sites	Inspection and measure	Fortnightly	Construction period	Monitoring Committee
(5) Increase in work related accidents	Traffic accidents, tunnel accidents, fire, etc.	Follow strict safety measures	Use of safety methods and equipments	Workplaces	Observation	Daily	Construction period and additional six months	Monitoring Committee
(6) Reduction of forest cover at dumping sites	Reduction of forest cover is 8.14 ha	Implement a environnemental restoration program	Regrowth Establishment and regeneration	Dumping sites	Observation measure and count	Twice a year for flora/Monthly for Fauna	Construction period and additional three years	Monitoring Committee with an ecologist
(7) Disturbance of some species due to noise and other activities	During construction some species will be affected.	Use low noise machinery/ some noise is not mitigable	Sound levels	Sites of Operations	Measure sound levels	spot checks	Construction period	Monitoring Committee
(8) Soil erosion due to tunnel muck dumping and access road construction	Length of the rubble is 1253 meter	Use appropriate soil conservation methods during construction (parallel with impact 6)	Methods	Dumping sites and access roads	Observation	Monthly	Construction period and additional six months	Monitoring Committee
(9) Ground Water Pollution from Tunnel discharge	Partially mitigable	Treating the waste water before discharging into the ground	Ground Water Quality parameters	Selected wells in the PIA	Measure	Once in two months	Construction period	Monitoring Committee
(10) Disturbances to the community from the workers	Partially mitigable	Awareness programs for the workers	Complaints from villagers	Villages	Enumeration	When required	Construction period and additional six months	Monitoring Committee
(11) Damages to Road due to increase in heavy traffic	Affected road is 18 km, 4 years.	Immediate repairing of the damaged roads	Road damages	Along the roads	Inspection and observation	Weekly	Construction period and decommissioning period.	Monitoring Committee

Impact	Nature of Impact	Mitigation Measure	Monitoring					
			Parameter	Locations	Method	Frequency	Duration	Responsibility
(12) Disturbance to the migration patterns of elephants	Migration routes from Power station to Randenigala Reservoir will be affected during operation.	Installing 8CCTVs to monitor elephants on the bed. And flash lights at 8points (cross sections) along right bank of the channel from the powerhouse	The presence of elephants on the river bed	Location where lights and CCTVs are installed.	Observation and monthly review	Automatic recording and monthly review	During construction and continue only if there is a need. Flash light will be used only if necessity is confirmed.	Monitoring Committee with the DWLC. The information will be useful for DWLC.
(13) Loss of private land at tunnel muck dumping site in Kohombagana	5.79 ha would be affected by temporary facilities in Kohombagana.	Payment of compensation for the loss of land at Rs. 100,000 per acre	Amount paid	Village	Check and verification	Twice	At the time of valuation and paying compensation	Monitoring Committee

Chapter 9 Basic Design

9.1 General

The design in the Study (basic design) is carried out at more detailed level than conducted in a feasibility study on a hydropower project, in accordance with S/W for the Study. Main outputs of the basic design are listed below:

Main features of facilities for the Project

- Drawings of general plan and profile of the Project
- Drawings of plan and profile of main civil structures (headrace tunnel, surge tank, steel penstock, powerhouse, and outlet) and , access adit
- Plan of layout of main equipment at powerhouse (those are included in the above drawings)
- Plan of layout of main equipment at switchyard (those are included in the above drawings)
- Single-line diagram

The Project is to connect the existing intake for the expansion and a new powerhouse to be arranged next to the existing powerhouse with waterway parallel to the existing waterway. Because the two new generating units are to be installed and the existing powerhouse has three units, the unit to be installed at the existing powerhouse side is named Unit No. 4 and the other is called as Unit No. 5.

9.2 Maximum Allowable Vibration due to Blasting against Existing Structures

Open-air works and underground works of the Project are to be carried out near the existing Victoria dam, intake facilities, waterway and powerhouse. Hence, vibrations caused by blasting should be controlled to prevent the existing facilities from being damaged. The maximum allowable velocity of vibration on the existing structure is determined as 2 cm/s by following reasons;

(1) According to the results of inspections conducted in 2000 for the waterway tunnel of the Victoria Hydropower Station, the existing tunnel is in a good condition to function.

(2) However, the new waterway will be adjacent to the existing arch dam and waterway in operation, therefore, the allowable velocity of vibration shall be in safe side.

(3) The actual value of the allowable value applied to the similar expansion projects in Japan which were carried out by J-Power was 2 cm/s. The limit of 2 cm/s means that the safety factor of around 15 is considered against vibration to cause tensile failure in concrete.

An examination on the tunnel alignment, construction planning, preparation of construction schedule, etc. have been carried out in consideration of the limit of 2 cm/s in the basic design.

9.3 Waterway

9.3.1 Route Setup

Construction of the intake, the headrace tunnel approximately 20 m in length from the intake gate, and the access adit, preparation of the open space for surge tank, and reclamation of the powerhouse space for the Project were already completed, therefore the new waterway is arranged to connect them.

The distance between the existing and the new headrace tunnels is set to 36 m to limit the velocity of vibration on the existing headrace lining concrete to 2 cm/s.

It was confirmed that the vertical and horizontal depth of the tunnel cover is sufficient to keep the stability of the surrounding rock against the internal water pressure in the new waterway.

9.3.2 Headrace

A 5 km long headrace tunnel is designed as a single line pressure tunnel with a circular section.

The inner diameter of the headrace tunnel is determined as 6.6 m to minimize the sum of annualized cost consisting of annualized construction and O&M costs of the headrace tunnel, and power revenue loss due to the head loss.

Four types of tunnel support pattern are set depending on the rock condition with reference to the existing headrace tunnel support patterns.

9.3.3 Penstock

The penstock is designed as a single line tunnel section 575 m long and a two-line open-air section approximately 200 m in length.

The inner diameter of the penstock in the tunnel section is determined as 5.6 m by using the same method applied to the headrace tunnel. The inner diameter of the open-air section is determined as 3.95 m so as to have the same current velocity upstream and downstream of the bifurcation.

The internal pressure applied to the penstock design is assumed as the sum of the static water pressure and the rising pressure due to water hammer or surging in the condition of the full load rejection (Q 140 $m^3/s \rightarrow 0$ m^3/s, closure time 5 s).

Four types of tunnel support patterns are set depending on the rock condition with reference to the tunnel section support patterns of the existing penstock.

9.3.4 Surge Tank

The new surge tank will be constructed east of the existing surge tank in the open space. Restricted orifice type, which is of the same type as the existing surge tank, is applied to the new surge tank. Dimensions of the new surge tank are set with reference to the existing surge tank, and the results of the surging analysis which was carried out under the condition to the full load rejection (Q

140 m^3/s → 0 m^3/s, closure time 5 s) and sudden load up (Q 70 m^3/s → 140 m^3/s, opening time 5 s) satisfies that the maximum surging level is lower than the top of the surge tank and the minimum surging level is higher than the top of the headrace.

The new surge tank satisfies Thoma-Schuller's condition of stability, therefore the new surge tank ensures stability against water level fluctuation.

9.3.5 After-Bay

The new after-bay consists of as the guide wall and the over-flow weir. Since the maximum discharge of the new power station is the same as that of the existing power station, the dimension of the new after-bay is set at the same dimension as the existing after-bay.

As to the weir, in case of lowering the elevation of the top of weir from EL. 230 m, it is necessary to excavate the riverbed in downstream of the weir, and when the existing power station is operated, the discharged water from the existing power station will flow back to the new after-bay. Hence, the top elevation of the new weir is set at the same elevation of the top of the existing weir of EL.230 m.

9.3.6 Access Adit Plug Concrete

The existing access adit has 400 m in length with wagon-shape of one circular arc (7.2 m × 7.2 m). This access adit will be used for the Project.

In Sri Lanka, it is common to install an access manhole by using an adit constructed on the middle way of the headrace tunnel for future maintenance works, hence the access manhole with 2 m in inner diameter will be installed in plug concrete of the access adit, to make it possible to carry in large-size machines in the new headrace tunnel.

The plug concrete is designed to resist the internal pressure of the headrace with its shearing force acting on the invert.

9.4 Hydromechanical Equipment

9.4.1 Steel Penstock

Steel penstock will be installed from the downstream of the surge tank to the inlet valve The penstock of 575 m long from the surge tank is a single line tunnel section. The steel penstock bifurcates at the tunnel portal and reaches the inlet valves in the open-air section 175 m long for Unit No. 4 and 160 m long for Unit No. 5 from the bifurcation. A portal valve will be installed downstream of the bifurcation. The inner diameter of the steel penstock is 6.6 m at the surge tank and contracted to 5.6 m through the tunnel section. Downstream of the bifurcation, the diameter becomes 3.95 m in each line. At the end of the inlet valve side, the diameter is contracted to 2.85 m to connect the inlet valve.

Design internal pressure is estimated approximately at 1.6 MPa at the surge tank side and approximately at 3.4 MPa at the inlet valve end. Design external pressure for the steel penstock in the tunnel section is assumed as 0.6 MPa due to contact grouting pressure.

According to the records on the previous construction works, the rock condition in the tunnel section is expected to be good, therefore the rock is expected to bear 20% of the internal pressure of the steel penstock in the section of 100 m upstream of the tunnel portal to the surge tank with enough depth of rock cover.

With the above-mentioned conditions, SM570Q in JIS G 3106 is applied to the material of the steel penstock. The thickness of the steel plate is calculated as 19 mm to 34 mm in the tunnel section and as 23 mm to 30 mm in the open-air section.

Stiffening plates will be attached to the steel penstock in the section where the rock is expected to bear the load.

The existing trifurcation is of external reinforced type, but the new bifurcation is determined as internal reinforced Y-shape type to reduce the head loss.

9.4.2 Portal Valve

It is common in Sri Lanka to install a portal valve immediately downstream of the bifurcation of open-air section of the penstock, to deal with unexpected contingencies like malfunction of inlet valve. In the Project, in accordance with the above, portal valves are to be installed immediately downstream of the bifurcation in the open-air section.

Expected usage of the portal valve is i) alternative function of the inlet valve during its accidents and ii) maintenance use with one-unit operation.

9.4.3 Outlet Gate

Outlet gates will be installed between the outlet of the draft tube and the after-bay for maintenance use. Main features of the gate are of slide gate type with 3.7 m in effective width, 3.7 m in effective height and 23.7 m of design water head. Two leaves of gates will be furnished for one draft tube. Gate slots will be installed in the both sides of piers of the draft tube. Opening and closing operation will be done by the existing gantry crane. Rail tracks for the existing gantry crane will be extended to the new outlet gate location for common use of the existing and new gates.

9.4.4 Access Manhole

The access manhole with inner diameter of 2 m will be installed in plug concrete of the access adit for future maintenance works. The access manhole consists of 10 m long steel liner with 2 m diameter and bulkhead attached by the bolts on flange at the junction of access adit and headrace.

The bulkhead will be opened and closed with a hoist crane suspending from a H-shape steel beam attached to the top of the access adit.

9.5 Power Station

9.5.1 Civil Structure

(1) Layout of Power Station

As the result of the comparison study on the three alternative options, it becomes obvious that the basic option in which the new powerhouse is to be constructed next to the existing powerhouse is the optimal from the economical and environmental points of view. The new powerhouse will be constructed by unifying it with the existing structure for the convenience of operation and maintenance works.

(2) Salient Feature of Civil Structure

The dimensions of the new powerhouse are determined based on the conditions of electromechanical equipment such as the turbine, generator, overhead traveling crane and so on. The structural calculations have not yet been executed.

1) Height

a) The elevation of the turbine center is lowered by 4 m from the turbine center of the existing unit due to the increase of draft head.
b) Lifting height of the overhead traveling crane becomes 1 m higher than that of the existing crane due to heavier equipment.
c) Height of the new powerhouse from bottom of the draft to the top of crane becomes 32.7 m which is 5.7 m higher than the existing powerhouse due to the increase in height of the draft tube, turbine and generator.

2) Width (Upstream-Downstream Direction)

The width of the powerhouse is determined as 37 m based on the sizes of the turbine, generator, inlet valve and necessary spaces for the auxiliary equipment. The crane span is 17 m which is 1.7 m wider than the existing due to the larger size and unit capacity.

3) Length

The length of the powerhouse is 69 m based on the necessary distance of each unit and a space for the erection bay. The existing overhead traveling crane and erection bay are not available for the new powerhouse because the new crane span is wider than that of the existing crane.

4) Elevation of Each Floor

The elevation of the erection bay is designed at EL.242.00 at the same elevation as the existing, in consideration of the carry-in route for equipment and materials. The new and the existing powerhouses are connected through the tunnel at generator floor (EL.230.25).

(3) Layout of Electromechanical Equipment

Floor elevations of main electromechanical equipment are shown in **Table 9.5.1-1**.

Table 9.5.1-1 Floor Arrangements

Main Equipment	Floor Elevation
OHT Crane	EL 249.00
Ventilation Plant	EL 249.00
Transformer	EL 242.00
Erection Bay	EL 242.00
Work Shop	EL 242.00
Cable Gallery	EL 238.00
Ventilation Gallery	EL 238.00
Transformer Oil Water Separation Pit	EL 238.00
Storage Area	EL 238.00
Battery	EL 230.25
AC/DC Control Board	EL 230.25
Unit Control Board	EL 230.25
Low Voltage Cub.	EL 230.25
Air Compressor Room	EL 226.00
Oil Treatment Room	EL 226.00
Motor Control Center	EL 226.00
Governor Oil Pressure Tank	EL 226.00
Turbine Control Board	EL 226.00
Fire Distinguish System	EL 226.00
Governor Cabinet	EL 226.00
G.V.Servo Motor	EL 226.00
Inlet Valve	EL 220.00
Inlet Valve Control Board	EL 220.00
Inlet Valve Oil Pump	EL 220.00
Drainage Pump	EL 220.00
Drainage Pit	EL 220.00

9.5.2 Electromechanical Equipment

Main expansion units are composed of 2 units of the hydraulic turbine with rated output of 122 MW at effective head of 191.50 m (at 1-unit operation) and turbine discharge of 70 m^3/s/unit, and the generator with rated capacity of 140 MVA.

The turbines, generators, auxiliary equipment such as cooling water and drainage system, 16.5 kV indoor switchgear equipment such as parallel-in circuit breaker, operation control system and overhead traveling crane are to be installed in the powerhouse. Main transformer will be installed outdoor and connected to the generator through the parallel-in circuit breaker and disconnecting switches. The generator voltage is stepped up from 16.5 kV to 220 kV by the main transformer. Generated power is transferred to 220 kV outdoor switchyard by through 220 kV power cables and to demand sides by the 2-circuit Kotmale and 1-circuit Randenigala transmission lines.

(1) Turbine Output

Turbine output is calculated with an effective head and water discharge.

Under normal effective head 191.5 m (1-unit operation), the output per unit is 122,000 kW.

(2) Turbine Type

In the case of the Francis type, applied effective head ranges are from about 50 to 500 m, and applied ranges of the specific speed are from 70 to 350 m-kW.

According to the calculation, the specific speed of this plant is estimated at 132 m-kW, which is in the above range.

Therefore, in consideration of the applying head, specific speed, experiences and examples applied to similar projects, Vertical Francis turbine is selected as the most appropriate type of turbine.

(3) Rated Speed

Based on the equation standardized by JEC-4001 and by using the limited specific speed as a target, revolving speed is calculated. After that, the rated speed is determined as 300 min^{-1}.in consideration of the number of poles with system frequency of 50Hz and economic validity.

(4) Turbine Center

The turbine center has to be low enough to prevent the runner from cavitations. The appropriate draft head of the turbine is calculated in consideration of tailrace water level, cavitations coefficient and vapor pressure

In this plant, the draft head is defined as -8.0 m mainly based on the cavitations coefficient 0.093 (standard value of the Institute of Electrical Engineers of Japan). In consideration of runner height 0.85 m (distance between the end of the runner and the center of the runner) and tail race water level of EL.230.72 m, which is under 1-unit rated operation, the center of the runner is calculated as EL.224 m.

(5) Inlet Valve

Type of inlet valve adopts the by-plane type controlled by oil servo motor.

This inlet valve shall withstand the maximum hydraulic pressure and full flow shutdown capacity.

(6) Generator

Three-phase alternating current synchronous generator, vertical, semi-umbrella type is adopted. Rotation direction is anti-clockwise in consideration of the upper side space of the generator.

(7) Generator Capacity

Generator rated capacity is defined as 140 MVA.

(8) Operation Control System

For operation of this power plant, the one-man control system is adopted for the turbine and generator.

The power plant is controlled in the control room in existing power plant. SCADA system is adopted for the control.

Visual integrated information is to be indicated with a plasma display set on each control desk, for operators to easily watch for monitoring.

The large size plasma display will be also installed beside the existing control board or appropriate place in the existing control room.

(9) Main Transformer

From the viewpoint of transportation limitation, a special three-phase transformer or three units of single-phase transformers will be adopted.

The capacity of the main transformer is defined as 145 MVA in consideration of the generator capacity, reactive power and station service power capacity.

(10) Over Head Traveling Crane

The maximum capacity of the main hook of the overhead traveling crane is defined with the maximum weight of installed equipment parts.

Generally the rotor of the generator is the heaviest equipment part. It is estimated at 192 ton in the Study.

The rated capacity of the over head traveling crane includes weights of connection beam, wire ropes and hooks.

The rated capacity is estimated at 230 t (115 t × 2 units) or more, however the maximum weight may be different in the manufacturer’s design, therefore, the rating will be reviewed during the detailed design.

9.6 Power System Analysis

Study Team conducted power flow analysis, short circuit analysis and transient stability analysis for the scenarios of Hydro Maximum Night Peak and Thermal Maximum Night Peak., in consideration of the installed capacity (114 MW × 2 units) determined in the basic design.

Many over-loaded transformers would be observed in the power system less than 132 kV, and low voltage of the buses would be observed because most of small hydro-power plants would be out of service in the scenario of Thermal-Maximum. However these problems would not depend on Victoria Expansion Project, and the result of the analysis shows that any problems of the power system would not be occurred by the expansion.

Chapter 10 Construction Plan and Cost for Construction

10.1 Temporary Facility Work

10.1.1 Concrete Aggregates

As outcrops are found at the project site, it is estimated that the volume of soil and sand excavation is not so much. Hence, mucks from the waterway tunnel, the surge tank and the powerhouse will be temporarily stocked in the yard and processed into fine and coarse aggregates in the crushing plant.

10.1.2 Spoil Bank

The alteration of land for the spoil bank shall be minimized from the environmental point of view because the project site is designated as the environmental conservation area. Therefore the following 5 candidates for the spoil bank are selected from the areas which were altered in the time of construction of the existing power station: (1) previous quarry site for the dam, (2) previous spoil bank for headrace tunnel, (3) previous temporary facilities area for the existing powerhouse, (4) previous spoil bank for the existing powerhouse, (5) land 2.4 km downstream from the existing powerhouse.

The candidates for the spoil bank are shown in **Figure 10.1.2-1**.

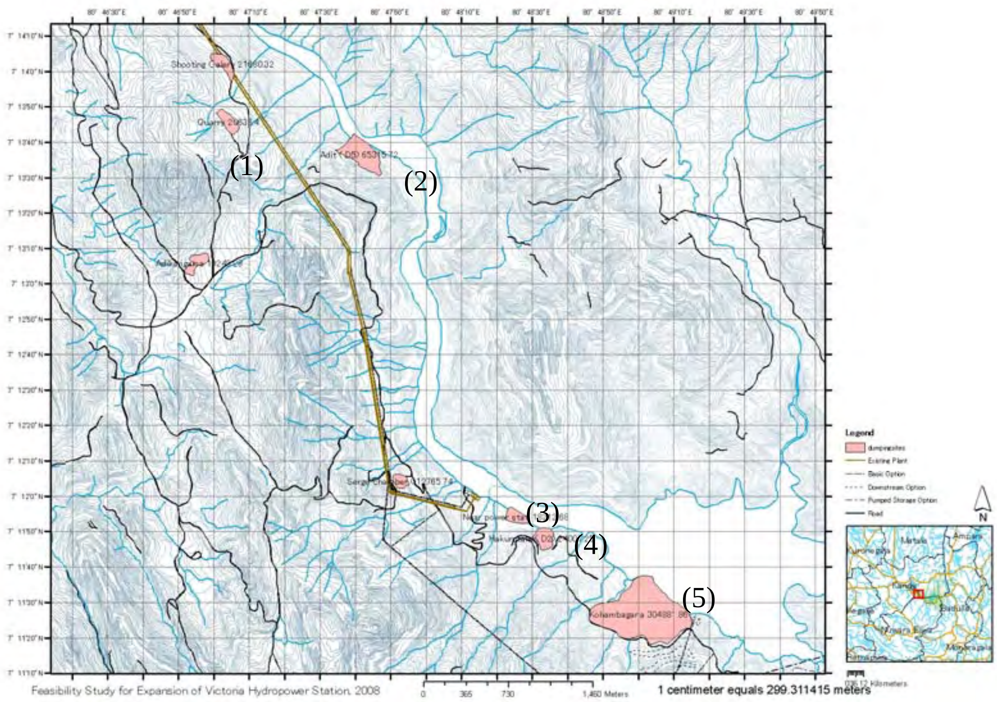


Figure 10.1.2-1 Location of Spoil Bank

The estimated capacities of each candidate for the spoil bank are shown in **Table 10.1.2-1**.

Table 10.1.2-1 Estimated Volume of Spoil Bank

No	Location	Estimated Area (m^2)	Estimated Volume (m^3)	Remark
(1)	Previous Quarry Area	12,800	160,000	
(2)	Previous Spoil Bank for Headrace	57,000	427,000	
(3)	Previous Temporary Area for Powerhouse	9,600	72,000	
(4)	Previous Spoil Bank for Powerhouse	4,000	40,000	
(5)	Stream at 2.4km Downstream of Powerhouse			Cultivated Area (Partially)
		Total	699,000	> 666,225 m^3

10.1.3 Temporary Facility Area

The candidates for the temporary facilities area and their details are shown in **Figure 10.1.3-1** and **Table 10.1.3-1**, respectively.

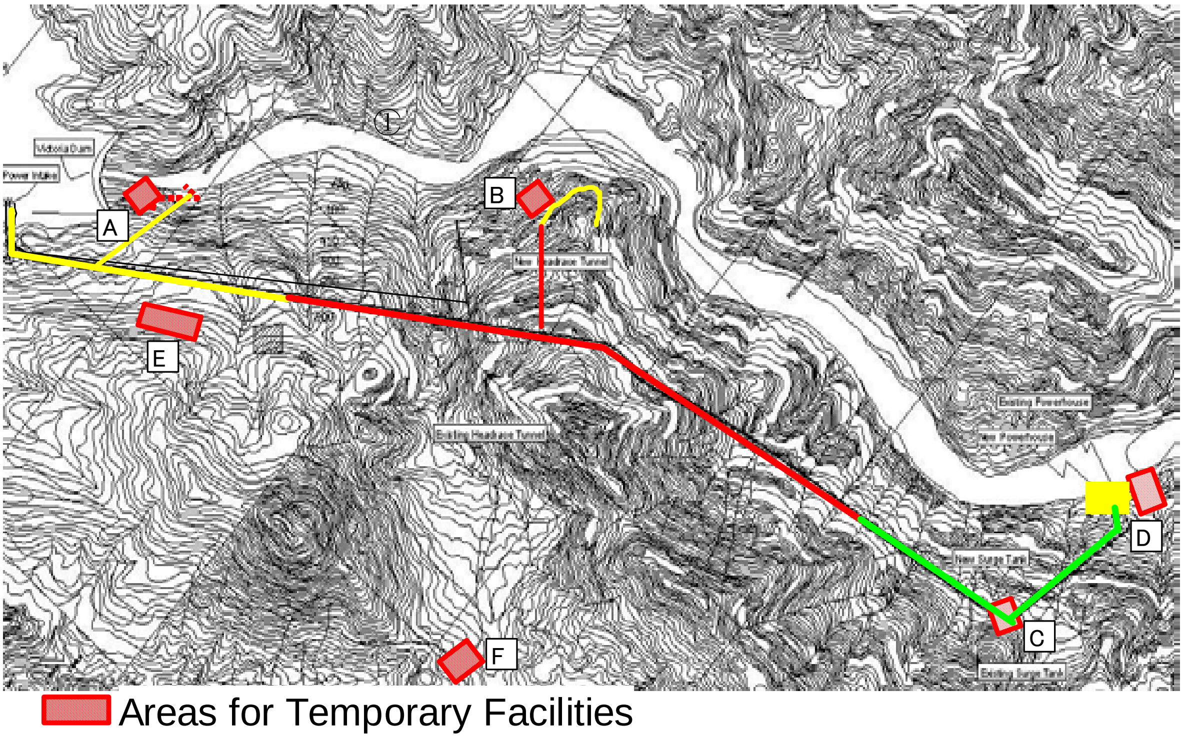


Figure 10.1.3-1 Location of Candidate for Temporary Facility Area

Table 10.1.3-1 Temporary Facility Area

No	Candidate for Temporary Facility Area	Estimated Area (m^2)	Location
A	Headrace Tunnel (Upstream) Area	2,000	Downstream of Dam right Abutment
B	Headrace Tunnel (Middle stream) Area	2,400	Portal of Existing Work Adit
C	Surge Tank Area	2,200	Existing Surge Tank
D	Headrace (Downstream) Penstock Powerhouse & Switchyard Area	3,500	Downstream of Powerhouse (CEB's Land)
E	Concrete Facilities	12,100	Temporary Facility Area for Dam
F	Construction Buildings	36,000	Near Circuit Bugalow (CEB's Land)

10.1.4 Improvement of Access Road

The access roads which were used for the construction of the existing power station will basically be diverted to the Project in order to minimize environmental impacts. The access roads to be repaired and/or improved are shown in **Table 10.1.4-1**.

Table 10.1.4-1 Access Road Improvement

Access Road to be Improved		Estimated Length (m)
Victoria Dam:	Temporary Facility Area A (Work Adit for Upsteam of Headrace Tunnel)	300
Tunnel Office:	Temporary Facility Area B (Work Adit for Middlesteam of Headrace Tunnel)	1,000
Powerhouse:	Temporary Facility Area D & Spoil Bank (3)	300
Existing Road:	Spoil Bank (4)	300

10.2 Main Work

10.2.1 Main Structures

Main structures are shown below.

Dam (Existing)...................Concrete Arch Type
Height: 112 m
Crest length: 520 m

Intake (Existing) ....Inclined Surface Intake Type

Headrace Tunnel ....Concrete Lining Type
Inner Diameter: 6.6 m
Length: 5,003 m

Surge Tank ....Underground Orifice Type
Inner Diameter: 20 m in upper part shaft, 6.6 m in lower part shaft
Height: 117 m in upper part shaft, 32.9 m in lower part shaft

Penstock.............................Tunnel Section Inner Diameter: 6.6 m to 5.6 m
Length: 575 m
Open-air Section Inner Diameter: 3.95 m to 2.85 m
Length: 175 m (unit No. 4), 160 m (unit No. 5)

Powerhouse........................Surface Type
Width 37 m × Height 44 m × Length 69 m

Turbine...............................Vertical Fransis 122 MW/unit × 2 units, 300 rpm

Generator ....140 kVA/unit × 2 units, 50 Hz

Main Transformer ....Outdoor Type140 kVA/unit × 2 units
Primary 16.5 kV, Secondary 220 kV

Cable Duct (Existing) ....Underground Culvert Type

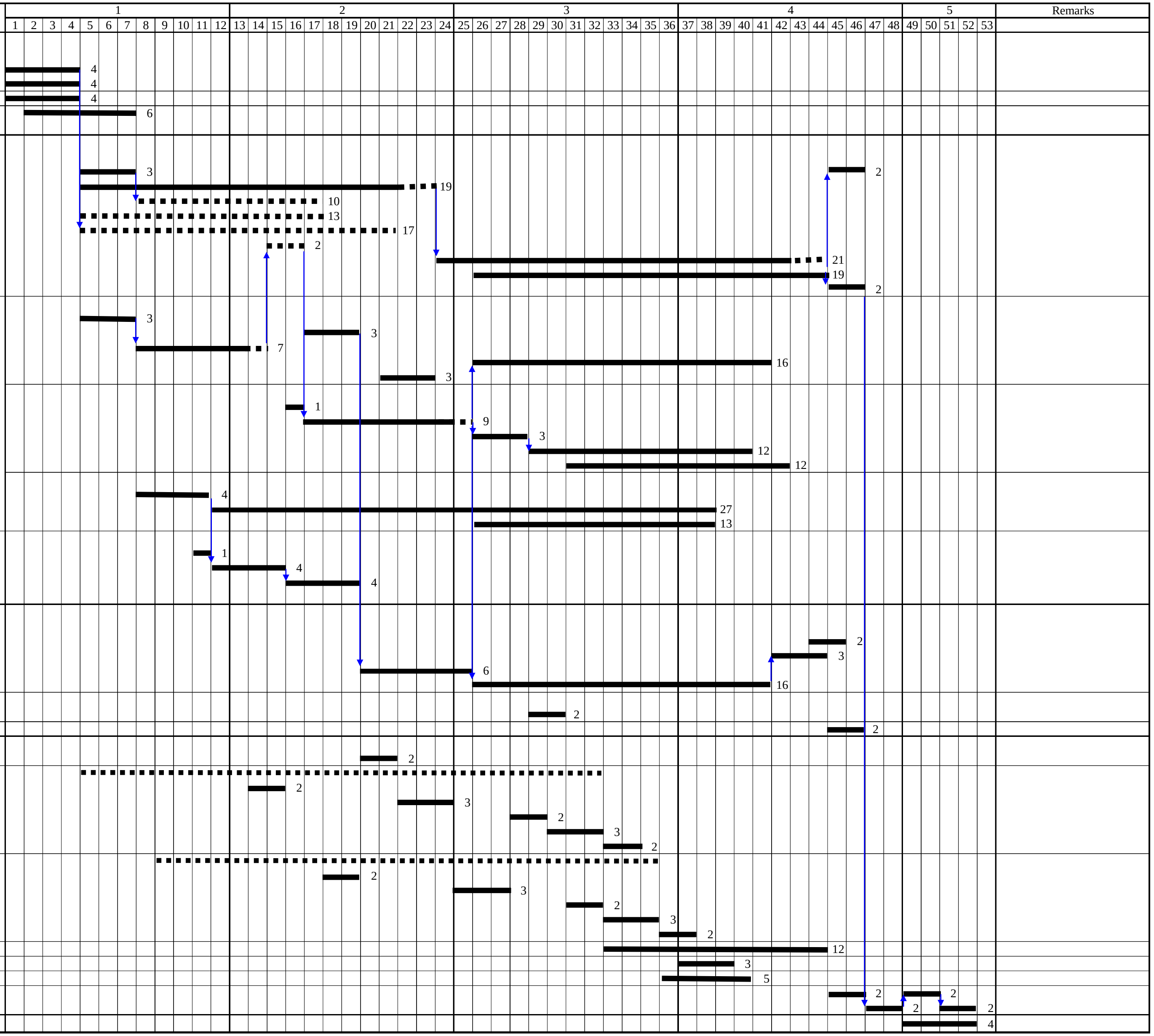
Outlet ....Width 38 m × Length 44 m

Switchyard ....Outdoor Type (in the existing space)

10.2.2 Construction Plan and Schedule

The construction period is estimated at 52 months. The critical path of the construction works for the Project is the headrace tunnel works. The construction schedule for the Project is shown in **Figure 10.2.2-1**.

Description	Quantity	Unit
1 Preparatory Works		
1.1 Access Road		
(1) Improvement of Existing Road	1	LS
(2) Access to Downstream of Dam	300	m
1.2 Temporary Power Supply	1	LS
1.3 Camp and Office for CEB&Engineer	1	LS
2 Civil Works		
2.1 Headrace Tunnel		
(1) New Work Adit & Plug Concrete	300	m
(2) Tunnel Excavation	252,700	m^3
A-1 Face		
A-2.1 Face		
A-2.2 Face		
A-3 Face		
(3) Concrete Lining	81,500	m^3
(4) Grouting	34,600	m
(5) Plug of Existing Work Adit	1	LS
2.2 Penstock		
(1) Open Excavation		m^3
(2) Concrete		m^3
(3) Tunnel Excavation	22,900	m^3
(4) Fill Concrete(around Steel Liner)	8,100	m^3
(5) Grouting	3,970	m
2.3 Surge Tank		
(1) Open Excavation	3,000	m^3
(2) Shaft Excavation	40,000	m^3
(3) Steel Liner (Tunnel)	1	LS
(4) Concrete Lining	9,000	m^3
(5) Grouting	4,150	m
2.4 Powerhouse		
(1) Open Excavation	44,000	m^3
(2) Concrete	24,300	m^3
(3) Finishing and Utility works	1	LS
2.5 Outlet		
(1) Coffering	1	LS
(2) Open Excavation	30,000	m^3
(3) Concrete	1,100	m^3
3 Hydromechanical Equipment		
3.1 Penstock		
Portal Valve	1	LS
Bifurcation	1	LS
Steel Liner (Open)	1	LS
Steel Liner (Tunnel)	1	LS
3.2 Outlet		
Gate Installation	1	LS
3.3 Access Tunnel Manhole	1	LS
4 Elecromechanical Equipment		
4.1 Overhead Traveling Crane	1	LS
4.2 #4 Unit		
(1) Draft tube	1	LS
(2) Spiral casing	1	LS
(3) Runner	1	LS
(4) Stator	1	LS
(5) Rotor	1	LS
4.3 #5 Unit		
(1) Draft tube	1	LS
(2) Spiral casing	1	LS
(3) Runner	1	LS
(4) Stator	1	LS
(5) Rotor	1	LS
4.4 Power Plant Equipment	1	LS
4.5 Main Transformer	1	LS
4.6 Switchyard	1	LS
4.7 Commissioning Test (dry test)	1	LS
(wet test)		
5 Miscellaneous Work		



Note: ▪▪▪▪▪ Design, Manufacturing and Transportation

▬▬ Installation, Assembly

Figure 10.2.2-1 Construction Schedule

10.3 Construction Cost

The construction cost has been estimated as of October 31st, 2008 in consideration of the site meteorology, geology, general area conditions, and construction scale.

10.3.1 Components of Construction Cost

The project cost consists of the following items.

(1)	Preparatory Construction Cost	:	Existing road improvement works, access road, temporary yards, power supply facilities for construction, office and camp facilities for CEB and Engineer.
(2)	Civil Works Construction Cost		
	Waterway	:	Work adit for headrace tunnel, headrace tunnel, surge tank, penstock, and outlet
	Powerhouse	:	Powerhouse foundation and structure
(3)	Hydromechanical Equipment	:	Penstock, portal valve, and outlet gates
(4)	Hydroelectric Equipment	:	Turbine, generator, related auxiliary equipment, and main transformer
(5)	Environmental cost:	:	Cost for compensation, mitigation, monitoring, etc.
(6)	Administrative and Engineering Costs	:	Administrative/management and engineering costs on detailed design and construction supervision (10% of direct cost)
(7)	Physical Contingency	:	10% for preparatory works, civil works, hydromechanical equipment, electromechanical equipment, administration and engineering fee, and environmental cost
(8)	Customs duties/tariffs	:	Not included
(9)	Price escalation contingency	:	Not considered
(10)	Interest during construction	:	Not considered

10.3.2 Project Construction Cost

The project cost with above conditions is estimated at US$222 million and shown in **Table 10.3.2-1** with foreign and local currencies.

Table 10.3.2-1 Project Construction Cost

No.	Item	Amount (US$)		
		Total	Foreign	Local
1	Preparatory Works	3,186,329	430,556	2,755,773
2	Civil Works	74,856,634	40,400,088	34,456,546
3	Hydromechanical Equipment	21,966,000	17,721,100	4,244,900
4	Elecromechanical Equipment	81,480,000	67,900,000	13,580,000
5	Environmental Cost	2,154,099	0	2,154,099
6	Adiministration and Engineering Fee	18,148,896	12,645,174	5,503,722
7	Contingency	20,179,196	13,909,692	6,269,504
	Project Construction Cost (1 to 7)	221,971,154	153,006,611	68,964,544

10.3.3 Disbursement Schedule

The annual required funding (disbursement schedule) is indicated in **Table 10.3.3-1** with foreign and local currencies.

Table 10.3.3-1 Disbursement Schedule of Project Construction Cost

No.	Item	1st Year		2nd Year		3rd Year		4th Year		5th Year		Total		
		Foreign (USD)	Local (USD)	Foreign (USD)	Local (USD)	Foreign (USD)	Local (USD)	Foreign (USD)	Local (USD)	Foreign (USD)	Local (USD)	Total (USD)	Foreign (USD)	Local (USD)
1	Preparatory Works	430,556	2,755,773									3,186,329	430,556	2,755,773
2	Civil Works	10,767,357	5,021,603	15,817,588	9,757,476	8,951,519	13,127,258	4,863,624	6,550,209	0	0	74,856,634	40,400,088	34,456,546
3	Hydromechanical Equipment	4,393,200	0	1,700,000	660,000	3,696,000	1,419,800	5,735,300	2,165,100	2,196,600	0	21,966,000	17,721,100	4,244,900
4	Elecromechanical Equipment	10,185,000	0	8,738,000	2,330,000	29,742,000	7,931,000	12,445,000	3,319,000	6,790,000		81,480,000	67,900,000	13,580,000
5	Environmental Cost	0	538,525	0	538,525	0	538,525	0	538,524	0	0	2,154,099	0	2,154,099
6	Adiministration and Engineering Fee	2,577,611	777,738	2,625,559	1,274,748	4,238,952	2,247,806	2,304,392	1,203,431	898,660	0	18,148,896	12,645,174	5,503,722
7	Contingency	2,835,372	909,364	2,888,115	1,456,075	4,662,847	2,526,439	2,534,832	1,377,626	988,526	0	20,179,196	13,909,692	6,269,504
	Project Construction Cost (1 to 7)	31,189,097	10,003,003	31,769,261	16,016,823	51,291,318	27,790,827	27,883,149	15,153,891	10,873,786	0	221,971,154	153,006,611	68,964,544

10.4 Implementation Plan for Project

The EPC (Engineering, Procurement, and Construction) or the DB (Design-Build) schemes, in which the construction work including the detailed design is ordered in a lump sum, as recently introduced for thermal power projects, could be applicable because unforeseeable physical risks involved in a hydropower project can be reduced. Compared EPC with the DB schemes, the DB is more preferable for CEB because they can get engaged in the design process more than EPC.

Therefore the DB and the conventional schemes (i.e. Contractor is determined by the bid after consultants execute the detailed design) are compared, provided that both schemes are executed under ODA finance.

(1) Schedule

In the case of ODA projects, loans are generally provided for the detailed design first, then for the construction works after appraisal by the donor based on the result of the detailed design.

However, it may be possible that loans to both the detailed design and the construction works will be provided at the same time, because the Project has i) less unforeseeable physical conditions such as geology, in comparison with usual hydropower projects, ii) less restriction for reservoir operation during expansion works and iii) no resettlement.

In either case, therefore, the completion will be at the end of 2016.

(2) Comparison of Both Schemes

Both schemes are compared in terms of i) risk and contract price, ii) contract package, iii) involvement of CEB on management for existing structures by blasting vibration, iv) security management for CEB’s facilities and v) environmental and social considerations.

As the result, the conventional scheme is recommended by Study Team.

Chapter 11 Economic and Financial Evaluation

11.1 Economic Evaluation

11.1.1 Methodology

Economic evaluation aims at measuring the "economic" impact brought about to a country by implementing a project from a viewpoint of national economy. Here, a comparison of costs and benefits expressed in terms of economic prices will be made by applying the Discount Cash Flow Method, which is widely adopted for such purposes.

11.1.2 Economic Cost of the Project

Initial investment cost, Operation & Maintenance and Replacement cost (including contingency) will be included in the cost stream.

11.1.3 Economic Benefit of the Project

Economic benefits (Power Benefit and Energy Benefit) are estimated based on alternative thermal power method for the cases of "with project" and "without project". The difference, i.e. incremental benefit, is considered as economic benefit of the Project.

11.1.4 Economic Evaluation

Evaluation indices like the Net Present Value (B-C) and Benefit Cost Ratio (B/C) at various discount rates, as well as EIRR are summarized in **Table 11.1.4-1**.

Table 11.1.4-1 Result of Economic Evaluation

	Evaluation Index	Evaluation Criteria	Discount Rate
NPV	US$353,154,000	> 0	8%
	US$235,639,000		10%
	US$158,203,000		12%
B/C	2.79	> 1	8%
	2.29		10%
	1.93		12%
EIRR	19.4%	> Opportunity cost of capital	8%
	19.8%		10%
	20.2%		12%

Note: EIRR also varies, because discount rate is used to obtain annualized cost of alternative thermal.

As a result, NPV results in positive (over zero), and EIRR exceeds 10% as opportunity cost of capital. Therefore the Project is judged as economically feasible.

Also the sensitivity analysis has revealed the following:

1) Due to the fact that the fuel cost used for evaluation lies in higher level, EIRR remains over 10% even with the case of 72% reduction of fuel cost (i.e. diesel US$38/bbl and coal US$44/MT).

2) Economic feasibility remains the same even with 1,260 MCM being tapped at the Polgolla weir.

3) In case of delayed development of base load power projects, and Victoria Hydropower Project is obliged to be operated for base load, and no economic feasibility is foreseen. Therefore, scheduled development of base load power is requisite for the Project.

11.2 Financial Evaluation

11.2.1 Methodology

Financial analysis aims at measuring the expected return on investment from a viewpoint of implementing body. Here Discounted Cash Flow method was adopted. Evaluation index to be obtained will be Financial Internal Rate of Return (FIRR) on investment. FIRR on investment will not be affected by financing conditions.

11.2.2 Financial Cost and Benefit of the Project

(1) Financial Cost

Financial cost of the Project includes the initial investment cost, cost for replacement of equipment, and Operation and Maintenance cost expressed at the financial prices.

(2) Financial Benefit

Financial benefit of the Project is the revenue to be earned by the electricity sale. The amount was calculated with an average unit energy rate in 2008 (USc12.157/kWh), multiplied by estimated volume of salable energy. In estimating the volume of salable energy, incremental energy was taken until 2018 when economic life of equipment for existing project would be completed, and energy generated by newly installed turbines thereafter.

Table 11.2.2-1 Financial Benefit

Period	Salable Energy (GWh)	Unit Price (USc/kWh)	Annual Revenue (US$)
2017-2018	9.4	12.157	1,143,000
2019-2066	325.0	12.157	39,510,000

Source: Study Team Calculation

11.2.3 Financial Evaluation

Financial Internal Rate of Return (FIRR) on investment was calculated based on the financial revenue. The result is shown in **Table 11.2.3-1**.

Table 11.2.3-1 Result of Financial Evaluation

Item	Result	Criteria
FIRR	9.6%	> interest rate

FIRR was calculated as 9.6%. Therefore, in order to look for financial feasibility of the Project, it was found that use of a loan with softer condition is necessary. In case the conditions for benefit calculation should be changed, some measures to increase financial income should be considered at the same time.

Chapter 12 Suggestions to Implement the Project

12.1 Matters to be Confirmed before Implementation of the Project

The following are matters to be confirmed for successful implementation before the Project implementation is commenced:

- Demand and supply plan on base power in the commissioning year of the Project as mentioned in **Chapter 4**, and,
- Review result on the water-use plan of the Mahaweli river in the DSWRPP as described in **Chapter 5**.

12.2 Items to Consider for CDM Application

Annual energy after the expansion increases slightly. There, however, may be a possibility to apply CDM (Clean Development Mechanism) to the Project, when effects on power generated by an alternative power plant for base demand instead of the Victoria Hydropower Station are considered after the Station is shifted from base power sources to peak power sources. It is indispensable for the Government of Sri Lanka and CEB, and the government of the investment country to discuss in details.

It is necessary for CDM application, i) to investigate new rules stipulated in a new protocol after expiry of Kyoto Protocol, ii) to clarify application conditions for projects financed by ODA loans, iii) to pay attention to the commencement date of examination on CDM, and iv) to preliminarily examine quantitative verification for reduction of greenhouse gas.

12.3 Proposal on Investigations and Design

Investigations and design for the Project during the detailed design to be conducted after the Study are proposed.

12.4 Proposal on Monitoring of Water Table Variation

Hydrological impacts such as temporary drawdown of wells located near the tunnel alignment were reported during the construction stage of the existing tunnel. Monitoring of water table variation is recommended for the purpose of measuring the hydrological impacts and planning adequate countermeasures during the construction stage of the new tunnel. Measurement of water table variation in boreholes and wells, meteorological observation and their monitoring plan are proposed.