CHAPTER 10

CONSTRUCTION PLAN AND COST FOR CONSTRUCTION

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10.1 General

10.1.1 Access to the Site

(1) Airway

Bandaranaike Airport in Katunayaka, which is located 35 km apart from the capital city, Sri Jayewardenepura, and the principal city, Colombo, is the only international airport in Sri Lanka. There are some airports for domestic flights in major cities, however no airport near the site. It takes 9 hours by direct flight from Narita Airport in Japan to the Bandaranaike Airport.

(2) Roads

The Project site is located in the Mahaweli river basin originated from the Central Highlands, and the site is about 150 km east-northeast from Colombo.

The electromechanical equipment, construction machines and construction materials imported from foreign countries are to be transported to the site after they are unloaded at the Colombo port. It takes about 4 hours to transport them from Colombo to the site through National Route No.1 via Kegalla and Kandy.

The roads to the site are almost paved and categorized in Class A. There seems to be no restriction in terms of weight limits and minimum turning radius, however the survey by the Contractor is needed when the detailed plan is determined at the initial stage of construction.

10.1.2 Temporary Power Supply during Construction

As the 33 kV transmission line from the existing Victoria Hydropower Station is located near the site, it is available for the Contractor to access to electricity during the construction works.

10.1.3 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. The volume of rock excavation and concrete for each main structure is shown in **Table 10.1.3-1**.

Table 10.1.3-1 Excavation and Concrete Volume for Main Structures

(Unit: m^3)

Structure	Rock excavation	Concrete
Headrace Tunnel	252,700	81,500
Surge Tank	40,000	9,000
Penstock	22,900	8,100
Powerhouse	35,000	24,300
Outlet	24,000	1,100
Work Adit	11,600	-
Total	386,200	124,000

Required volume of fine and coarse aggregates is estimated as follows.

$V = 124{,}000 \times 2.046 / 2.6 \times 1.125 = 109{,}775 \fallingdotseq 110{,}000\ m^3$

Where,

Aggregates mass per 1 m^3 concrete = 2.046 t/m^3

Aggregates specific gravity = 2.6

Loss at aggregates production = 12.5%

Assumed that the only 50% of mucks can be useful for concrete aggregates due to loss and time delay between production and usage, the potential volume of excavated rocks usable for aggregates is estimated by the following equation:

$386{,}200 \times 0.5 = 193{,}000\ m^3$

Therefore, the volume of mucks from the waterway tunnel works will be sufficient for concrete aggregates.

The fine aggregates may also be procured from the river bed at 5 km upstream from CEB's tunnel office, though further investigations are needed for quality, volume, and environmental impact, because natural sand was mixed for fine aggregates used for concrete placed in the existing powerhouse to keep quality of the fine aggregates.

The location and the site condition of the possible borrow area are shown in **Picture 10.1.3-1** to **Picture 10.1.3-3**.

Picture 10.1.3-1 Borrow Area for Sand Aggregate

Picture 10.1.3-2
Borrow Area for Sand Aggregate

Picture 10.1.3-3
Borrow Area for Sand Aggregate

10.1.4 Spoil Bank

(1) Required Volume for Spoil Bank

The required volume for the spoil bank is estimated in **Table 10.1.4-1.**

Here, the volume of mucks to be disposed in the spoil bank is calculated 1.5 times as much as the excavated volume in consideration of the over excavation and the expansion ratio of soil and rock. Furthermore the volume to be used for the concrete aggregates is neglected in calculation of the spoil bank volume, because there may be time delay between excavation works and concrete works.

Table 10.1.4-1 Excavation and Spoil Bank Volume for Main Structures

(Unit: m^3)

Structure	Excavation	Spoil Bank Volume
Headrace Tunnel	252,700	379,050
Surge Tank	43,000	64,500
Penstock	41,700	62,550
Powerhouse	44,000	66,000
Outlet	30,000	45,000
Work Adit	11,600	17,400
Others (5%)	21,150	31,725
Total	444,150	666,225

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 powerhouse: (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 10.1.4-1**.

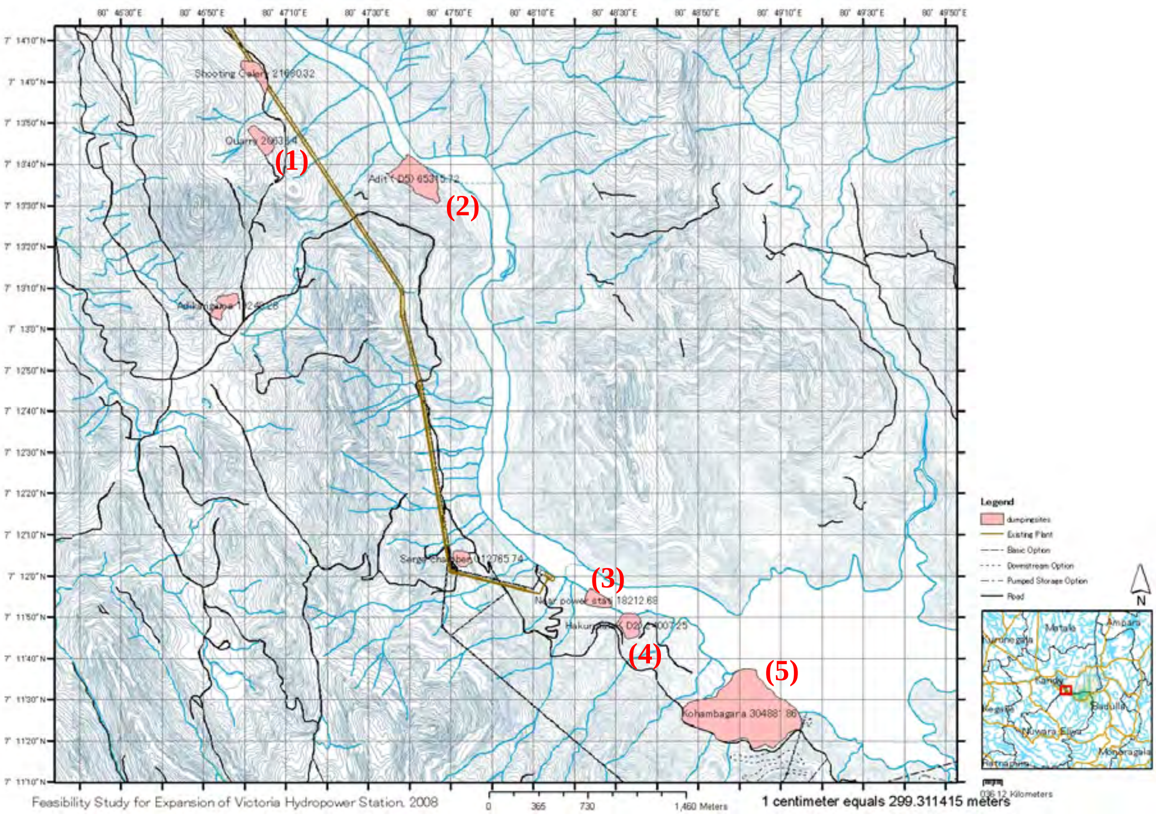


Figure 10.1.4-1 Location of Spoil Bank

The conditions of each candidate are shown in **Picture 10.1.4-1** to **Picture 10.1.4-5**.

Picture 10.1.4-1 Spoil Bank (1)

Picture 10.1.4-2 Spoil Bank (2)

Picture 10.1.4-3 Spoil Bank (3)

Picture 10.1.4-4 Spoil Bank (4)

Picture 10.1.4-5 Spoil Bank (5)

The estimated capacities of each candidate for the spoil bank are shown in **Table 10.1.4-2**.

The total of the candidates (1), (2), (3) and (4) can accommodate the whole required volume 666,225 m^3, but the candidate (5) shall be kept in reserve in the basic design, because each candidate will be required topographic survey, environmental study, and negotiation with the land owner.

Table 10.1.4-2 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 2.4 km Downstream of Powerhouse			Cultivated Area (Partially)
		Total	699,000	> 666,225 m^3

(2) Transportation to Spoil Bank

The total number of dump trucks for the transportation of mucks to the spoil banks is estimated as follows.

$$\underset{\text{(excavation volume)}}{444{,}150\ m^3} \times \underset{\text{(aggregate specific gravity)}}{2.6\ t/m^3} \div \underset{\text{(capacity of truck)}}{10\ t/track} = 115{,}500 \text{ trucks}$$

As for the transportation on the public road, it is necessary to repair and improve the existing road as well as to take heed noise and safety.

10.1.5 Temporary Facility Area

The items of main temporary facilities and their required area are shown in **Table 10.1.5-1**.

Table 10.1.5-1 Temporary Facility Area

No.	Item	Necessay Area (m2)
A	Headrace Tunnel (Up stream) Area	2,000 m2
A−1	Motor Pool for Construction Machinery	
A−2	Materials Storage Yard	
A−3	Other Buildings (Contractor's Office, Parking Lots etc.)	
B	Headrace Tunnel (Middle stream) Area	2,400 m2
B−1	Motor Pool for Construction Machinery	
B−2	Repair Shop	
B−3	Fabricating Yard for Reinforcement Bars	
B−4	Carpentory Shop	
B−5	Materials Storage Yard	
B−6	Other Buildings (Contractor's Office, Parking Lots etc.)	
C	Surge Tank Area	2,000 m2
C−1	Motor Pool for Construction Machinery	
C−2	Materials Storage Yard	
C−3	Other Buildings (Contractor's Office, Parking Lots etc.)	
D	Headrace(Down stream), Penstock, Powerhouse & Switchyard Area	3,500 m2
D−1	(Motor Pool for Construction Machinery)	
D−2	(Repair Shop)	
D−3	(Fabricating Yard for Reinforcement Bars)	
D−4	(Carpentory Shop)	
D−5	(Explosives Warehouse)	
D−6	(Other Warehouse)	
D−7	(Materials Storage Yard)	
D−8	(Other Buildings (Contractor's Office, Parking Lots etc.))	
D−9	(Tailrace Gate Assembly Yard)	
D−10	Penstock Assembly Yard	
D−11	Welding Shop	
E	Concrete Facilities	11,000 m2
E−1	Batching Plant	
E−2	Crushing Plant	
E−3	Aggregate Stock Yard	
E−4	Laboratory	
F	Construction Buildings	36,000 m2
F−1	Owner's & Engineer's Office & Camp	
F−2	Contractor's Office & Camp	
F−3	Laboir's Camp	

The candidates for the temporary facilities area and their details are shown in **Figure 10.1.5-1** and **Table 10.1.5-2,** respectively.

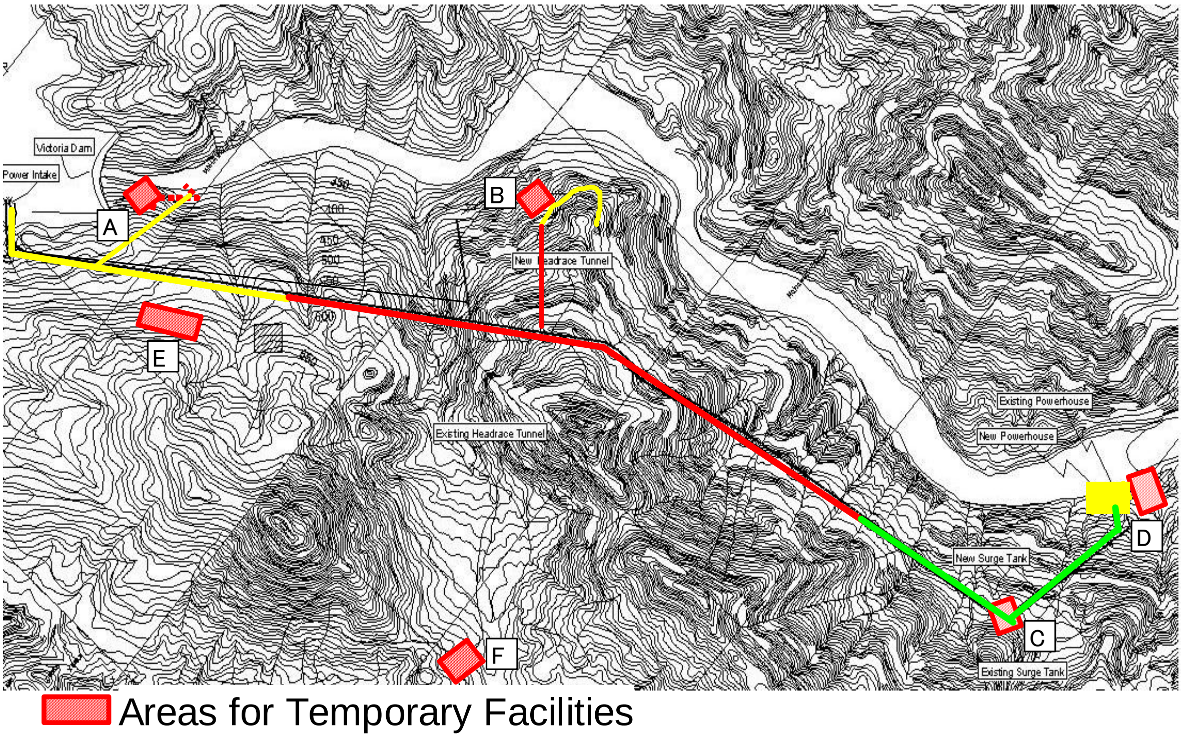


Figure 10.1.5-1 Location of Candidate Temporary Facilities Area

Table 10.1.5-2 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)

These temporary facilities will be demolished after the completion of the construction works, but the office and camp for CEB in the area F will be left, because they are utilized for the operation and maintenance.

10.1.6 Improvement of Access Road

The access roads which were used for the construction of the existing powerhouse will be basically diverted to the Project in order to minimize environmental impacts. The access roads to be repaired and/or improved are shown in **Table 10.1.6-1**.

Table 10.1.6-1 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 Construction Plan and Schedule

10.2.1 Basic Conditions

Main structures to be constructed in the Project are 1 line of headrace tunnel (L = 5,003 m, D = 6.6 m), surge tank (D = 20 m in upper part shaft and D = 6.6 m in lower part shaft), penstock (L = 575 m of tunnel part, L = 160 and 175 m of open part, D = 5.6 m to 2.85 m), and surface type powerhouse, etc. The total excavation volume is about 444,000 m^3, and the total concrete volume is about 124,000 m^3.

(1) Meteorology

The annual mean temperature at the Project site is 25.1°C. The monthly average maximum and minimum temperatures are 30°C and 20°C, respectively. In addition, the annual average rainfall is 1,375 mm, which do not constitute any negative meteorological conditions to cause major impacts on the schedule of open-air works. The countermeasures such as cooling water for concrete placement works during high-temperature periods may be required.

(2) Construction Materials

Although cement and reinforcement bars seem to be available from factories in Sri Lanka, they are planned to be procured from both domestic and offshore sources. The construction materials such as steel are to be fully procured outside the country. Most of aggregates for concrete will be produced from mucks generated from the tunnel and other excavation works, with crushing rocks at on-site aggregate plants.

(3) Number of Working Days

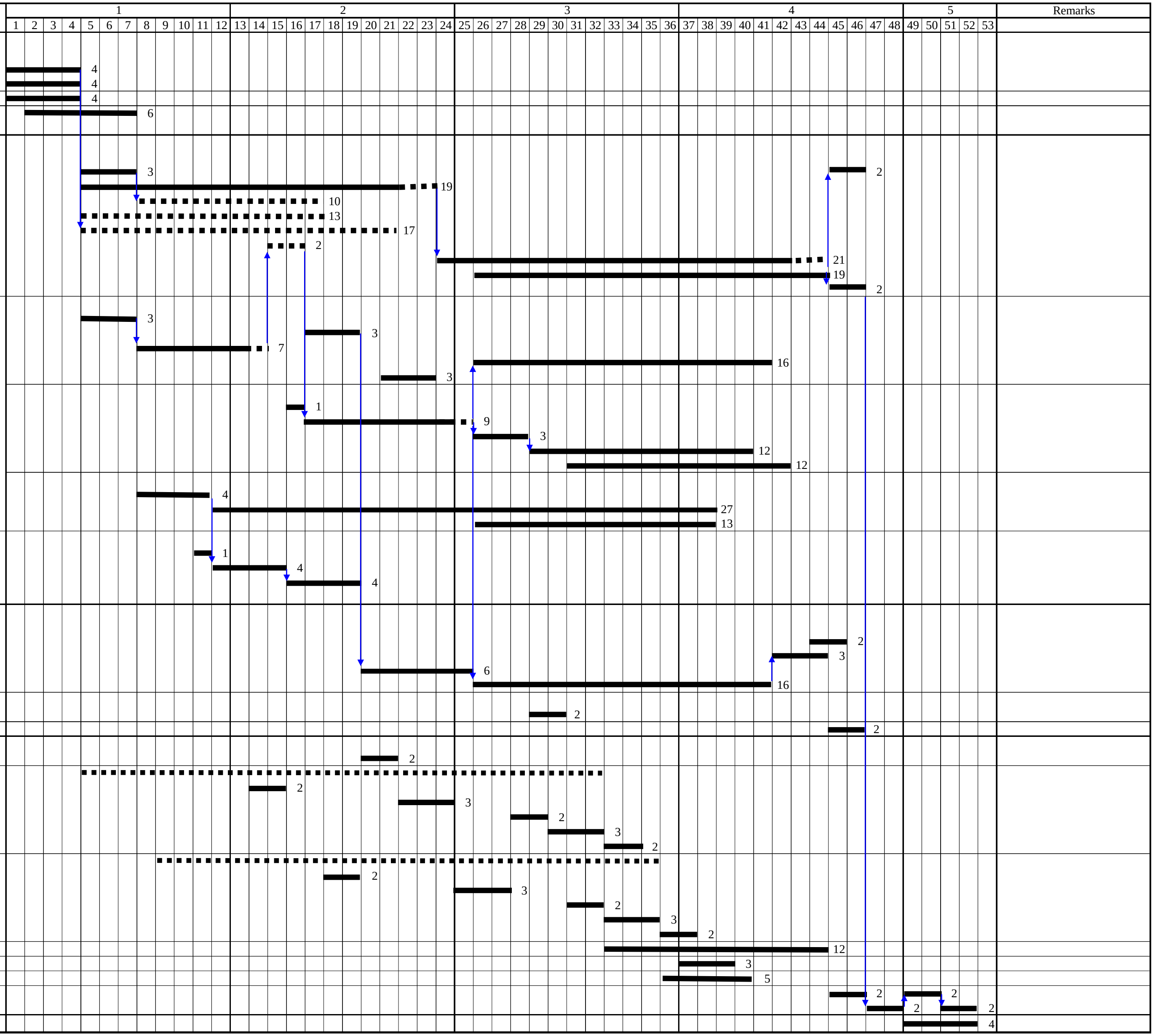
The working conditions are defined as follows based on the actual situation in Sri Lanka.

- 8:00 to17:00 except day-and-night work such as tunnel
- From Monday to Saturday except national holidays and poya days

10.2.2 Construction Plan and Schedule

Based on the basic conditions and work quantities described above, the construction plan and schedule are prepared. 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

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 (No. 4 unit), 160 m (No. 5 unit)

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

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

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

Main Transformer ....Outdoor Type145 MVA /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)

(1) Preparatory Work

The preparatory work includes the improvement of the existing roads, the construction of a part of the access road from the Victoria Dam right abutment to the work adit for the new headrace tunnel, the temporary power supply facilities for construction works, and the camp for CEB and engineers. These works should be completed under another contract before starting main civil works.

(2) Intake

The structure from the intake screen to the Ch.15 m of the headrace has been completed in the previous project, and it is filled with water now. The intake gate has also been installed in the gate shaft, therefore the existing headrace section will be dewatered after closing the intake gate and be connected to the new headrace tunnel in the Project. The water tightness of the gate shall be checked prior to this work.

(3) Headrace Tunnel

The headrace tunnel is of circular type and 5,003 m long with 8.0 m in diameter of excavation and 6.6 m in inner diameter of concrete lining.

As shown in **Figure 10.2.2-2**, the tunnel will be driven from the new access adit which will be constructed at the dam right abutment (A-1), the existing access adit located in the halfway point of the headrace tunnel (A-2.1 and A-2.2), and the portal of the penstock tunnel (A-3). The new access adit from the dam right abutment will have 300 m long and 6.8 m in diameter. The existing access adit is 400 m long and 7.2 m in diameter.

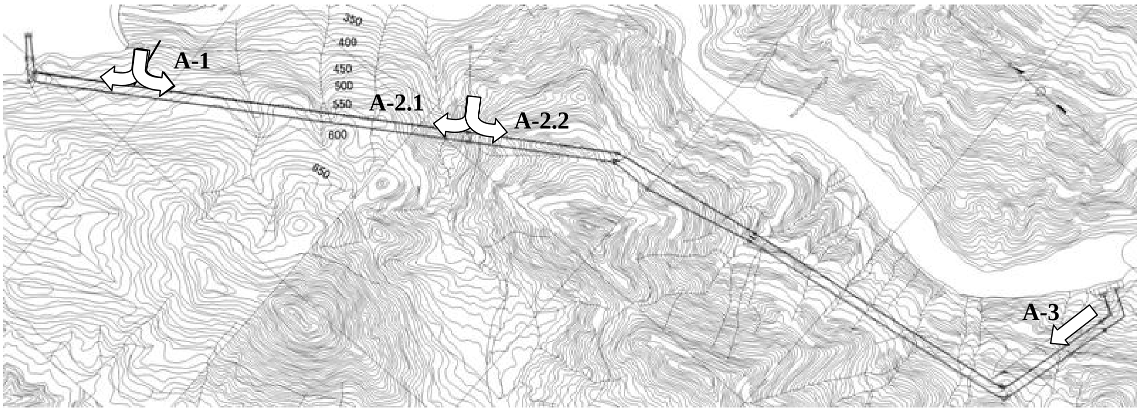


Figure 10.2.2-2 Excavation Procedure

The headrace tunnel will be excavated with the full face tunneling method by using 3-boom wheel jumbos, side dump type muck loaders and dump trucks. The tunnel supporting works will be done with shotcrete and rock bolts. Steel rib supports may be used as the support system in the new tunnel portal section and weak rock sections, if any.

The monthly progress of tunnel excavation is expected to be 125 m/month based on the actual records of tunnel excavation in the Upper Kotmale Hydropower Project (This actual records are corrected in consideration of the difference of the cross section area of tunnels) and based on the limitation of negative impact on the existing structures due to the blasting which is indicated in **9.2.5**.

The monthly progress in the tunnel portal section of 30 m is expected to be 30 m/month in order to keep the Sri Lanka's law for the blasting.

It is impossible to measure the impact on the existing headrace due to the blasting during power operation. Therefore, it is necessary to estimate the velocity of vibration on the existing headrace due to the blasting and to control the blasting to limit the velocity of vibration within allowable value. This estimation shall be based on the results of the trial blasting carried out prior to the tunnel excavation.

The trial blasting will be carried out at the face of the new access adit on the dam right abutment in manner of varying the loading amount of explosives in several times and of measuring the velocity of vibration with the vibrographs in the intake gate shaft and/or the dam inspection galleries.

To determine the explosive amount, the following empirical equation will be used to limit the velocity of vibration on the existing headrace not exceeding 2 cm/s [1].

$$V = K \bullet W^{\frac{2}{3}} \bullet D^{-2}$$

Where,

V	:	velocity of vibration (cm/s) → 2 cm/s
K	:	Coefficient related to blasting conditions → set by trial blasting
W	:	loading amount of explosive per rotation (kg)
D	:	distance from the center of blasting (m)→ 36 m

It is recommended to conduct such trial blasting at a few faces in the new adit, because K depends on characteristics of geology of the tunnel.

The lining concrete will be placed with three sets of 10 m long circular traveling steel form. The monthly progress of the lining concrete is expected to be 125 m/month per traveling steel form.

The cycle of the lining concrete work is expected to be 10 m/span with interval of 2 days (0.5 day for form setting + 1 day for concrete placing + 0.5 day for form removal).

The consolidation grout will be executed in the section where the strength of the lining concrete reaches to the designed strength.

The headrace tunnel work is critical path in the whole work schedule, therefore this work should be commenced immediately after the completion of preparation works. The construction period of the headrace tunnel is estimated at 17 months for the tunnel excavation and at 19 months for the lining concrete work.

(4) Surge Tank

The shaft excavation for the surge tank will be carried out in two steps: the pilot hole excavation and the enlargement excavation. The pilot hole will be excavated with a raise climber upward from the headrace tunnel or with a raise borer downward from the ground to the headrace tunnel, then widen with a reaming bit upward from the headrace tunnel. After completion of the pilot hole, the enlargement excavation will be executed with drilling and blasting method downward from the ground. The mucks will be dropped to the headrace tunnel through the pilot hole and then hauled outside with dump trucks through the penstock tunnel.

The construction period of the surge tank is estimated at 9 months for the shaft excavation and at 12 months for the lining with referring to previous results. The consolidation grout will take 1 month after the lining concrete work.

[1] Estimate on vibration of the Victoria dam due to the blasting which causes the maximum vibration of 2cm/s on the existing tunnel is shown in Appendix II.

(5) Penstock Tunnel

The excavation of the penstock tunnel will be executed with the same method as the headrace tunnel excavation. The monthly progress of the penstock tunnel excavation is expected to be 125 m/month as is the case with the same as the headrace tunnel excavation.

The backfill concrete placing around steel pipe will be commenced after the completion of the surge tank excavation, because the mucks from the surge tank will be carried out through the penstock tunnel. The backfill concrete will be placed with a concrete pump. The steel pipe installation and the filling concrete work will be carried out by turns.

The monthly progress of the penstock tunnel work is expected to be 36 m/month based on the estimated cycle-time; 12 days for steel pipe installation (6 m × 3 units) and 3 days for backfill concrete work.

(6) Penstock

The salient features of the steel penstock are shown as follows.

Type	Embedded and Exposed Type Steel Penstock
Design water head	353.5 m at turbine center level
Component	1 line (upstream of bifurcation), 2 lines (downstream of bifurcation)
Length (incl. steel lining)	750 m (unit No. 4) and 735 m (unit No. 5) of which 575 m is tunnel section
Inner diameter	6.6 m to 5.6 m (upstream of bifurcation) 3.95 m to 2.85 m (downstream of bifurcation)
Sharing ratio of internal pressure by bedrock	20% (excl. entrance of tunnel)
Bifurcation	Internal Reinforcement Type Y-Branch
Portal valve	Butterfly Type, 2 units (downstream of bifurcation)

The steel lining and the steel penstock are fabricated in the temporary factory near the site and transported to the respective tunnel with trailers.

Installation will be commenced after the completion of the excavation of the surge tank shaft and penstock tunnel. The section with 6.6 m in diameter will be brought from the surge tank shaft and installed to the given place in the tunnel. The installation is executed from both the upstream end and the downstream end simultaneously, and steel pipes are jointed finally just below the surge tank shaft. The parts of 5.6 m will be brought from the tunnel portal of the downstream side and installed from upstream to downstream.

The monthly progress of the installation work is expected to be 36 m/month based on the estimated cycle-time; 18 m/span with 15 days (12 days for connecting and welding 3 units of 6 m pipes:+ 3 days for concrete placing).

The bifurcation part is installed in the open area which is located at the end of tunnel part. The installation of the bifurcation part will be executed after the completion of installation of the penstock of 5.6 m diameter, then branch pipes will be installed continuously to near the portal valve. The downstream parts of the branch pipes will be installed from the power station side to the portal valve side. Finally the penstock will be jointed when the valve is installed at the last.

(7) Powerhouse

The powerhouse is of surface type which dimensions are 37 m wide, 44 m high and 69 m long.

The powerhouse excavation will be done by the bench-cut blasting method. The trial blasting shall be executed before commencement of blasting work in order to avoid damages to the existing powerhouse due to the vibration by the blasting. The trial blasting shall deploy several blasting patterns, and vibration due to blasting shall be measured in the existing powerhouse. The pre-splitting method may be effective if the vibration seems to exceed the allowable limit. If required, the chemical fracturing agent and/or the breaker without using explosives are also recommendable. It is important to monitor the vibration in the existing powerhouse during the excavation works.

After the excavation reaches the bottom of the powerhouse, the required machines and materials will be brought with temporary cranes, then base concrete works will begin. The concrete around the electromechanical equipment such as draft tube, casing, turbine, and generator will be cast, dividing primary and secondary stages.

After the completion of the crane girder in the erection bay, the assembly of overhead traveling cranes will begin in the erection bay. Following the completion of wall concreting and the crane girder, the turbine and generator installation will start with the crane. Finishing and utility works will be executed in parallel with the civil and the electromechanical works.

The powerhouse works is expected to involve 4 months for excavation works, 27 months for concrete works and 13 months for finishing and utility works.

(8) Hydraulic Turbine, Generator, etc.

1) Draft Tube

The installation, welding and assembling works of draft tube liner for Unit No. 4 will be started 14 months after the starting of the construction works. The installation work of the draft tube liner will be executed by using truck cranes.

2) Spiral Casing

After the completion of over head traveling crane installation, the installation of the spiral casing will be executed.

3) Hydraulic Turbine, Generator and Main Transformer

The installations of hydraulic turbine and generator will be started after the completion of the spiral casing. The hydraulic turbine of Unit No. 4 will be started 28 months after the starting of the construction works. The hydraulic turbine of Unit No. 5 will be started one month after the commencement of the hydraulic turbine of Unit No.4.

The assembling work of the stator of Unit No. 5 will be overlapped with the installation work of the rotor of Unit No. 4. As it is anticipated that works at the erection bay would be complicated, the works have to be conducted with maximum attention to safety. Main Transformers will be installed outside 37 months after the starting of construction works.

4) Auxiliary and Control Equipment

The installation work of turbine auxiliary equipment will be conducted after the hydraulic turbine installation. Control equipment will be installed after the generator installation.

Piping and cabling works, and the adjustment of each control board will be done at the same time as this period.

5) 220 kV Switchyard

The installation work of switchgear (220 kV CB, DS, CT, VT) will be started 36 months after starting of the construction works.

As the existing units, line and bus section are in operation, the installation work must be carried out within the new yard, not to affect operation of the existing facilities.

6) Commissioning Test

The dry test of Unit No. 4 will be started 45 months after starting of the construction works and take 2 months for the completion.

The wet test will be conducted continuously and also scheduled for 2 months for the completion. The commercial operation will be started after all tests including the load rejection test are completed.

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 Basic Criteria for Cost Estimate

The construction cost for the Project has been estimated for the calculation of financial amount and for the economic and financial evaluation of the Project.

(1) The unit prices of civil work items are estimated based on the actual contract prices of Upper Kotmale Hydropower Project in consideration of the price escalation.

The estimated exchange rates and the price escalation are as follows;

- Exchange rate as of Contract of Upper Kotmale (September 30th, 2006):
  US$1 = JPY117.90 = Rs.103.82
- Exchange rate as of Cost estimation (October 31st, 2008):
  US$1 = JPY98.40 = Rs.109.35
- Escalation ratio (from September 30th, 2006 to October 31st, 2008):
  Foreign Currency (US$): 107.4% (according to IMF World Economic Outlook 2008)
  Local (Rs.): 145.0% (according to IMF World Economic Outlook 2008)
- The unit prices are calculated as follows
  1) The foreign currency (JPY) and local currency (Rs.) portions of the unit price of respective work items are determined in reference to the contract prices of Upper Kotmale project.
  2) Both portion of the above unit prices are converted to US$ by using the exchange rate as of Contract date of Upper Kotmale (September 30th, 2006).
  3) The escalated unit prices as of October 31st, 2008 are calculated in manner that 107.4% is applied to foreign currency of the unit price and 145.0% to the local currency.

The construction costs for electromechanical equipment and hydromechanical equipment are estimated in consideration of international market prices in October 2008.

(2) Administration and engineering fee is estimated as 10% of the direct cost (total cost of preparatory works, civil works, hydromechanical equipment, and electromechanical equipment).

(3) Contingency of both foreign and local currencies is estimated at 10% of the total cost of preparatory works, civil works, hydromechanical equipment, electromechanical equipment, administration and engineering fee, and environmental cost.

(4) All costs are expressed in US Dollar and are assorted into the local currency and foreign currency portions.

(5) Unit prices and construction costs include taxes and duties to be paid except VAT, but for imported materials or equipment, local taxes and customs duties in Sri Lanka are not included.

(6) Price escalation and interest during the construction period are not included in the project cost.

The project cost, however, will not be the same as the cost to be borne by the executing agency for actual project implementation in the future. The estimated project cost may rise because the price escalation and interest during the construction will have to be paid by the executing agency. Furthermore, local taxes and customs duties will have to be paid when the construction equipment and materials are imported by the contractor.

10.3.2 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, 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

10.3.3 Project Construction Cost

The project cost estimated with above conditions is described in **Table 10.3.3-1** with foreign and local currencies.

Table 10.3.3-1 Project Construction Cost

No.	Item	Unit	Quantity	Unit Price(US$)			Amount (US$)		
				Total	Foreign	Local	Total	Foreign	Local
1	**Preparatory Works**								
1.1	Access Road	LS	1	356,235	91,078	265,157	356,235	91,078	265,157
1.2	Temporary Power Supply	LS	1	2,261,911	273,232	1,988,679	2,261,911	273,232	1,988,679
1.3	Camp and Office for CEB &Engineer	LS	1	568,183	66,246	501,937	568,183	66,246	501,937
	Total						**3,186,329**	**430,556**	**2,755,773**
2	**Civil Works**								
2.1	Headrace Tunnel								
	Work adit								
	Tunnel Excavation	m^3	11,600	75	55	20	870,000	638,000	232,000
	Shotcrete 5cm	m^2	3,600	17	13	4	61,200	46,800	14,400
	Shotcrete 10cm	m^2	400	38	28	10	15,200	11,200	4,000
	Rock Bolt 2m	nos	1,290	38	31	7	49,020	39,990	9,030
	Rock Bolt 3m	nos	150	49	40	9	7,350	6,000	1,350
	Steel Support	ton	23	1,813	1,543	270	41,699	35,489	6,210
	Headrace Tunnel								
	Tunnel Excavation	m^3	252,700	73	50	23	18,447,100	12,635,000	5,812,100
	Shotcrete 5cm	m^2	75,200	21	14	7	1,579,200	1,052,800	526,400
	Rock Bolt (D25) 3m	nos	27,420	52	43	9	1,425,840	1,179,060	246,780
	Concrete, lining	m^3	81,500	146	84	62	11,899,000	6,846,000	5,053,000
	Re-bar	ton	3,260	1,854	248	1,606	6,044,040	808,480	5,235,560
	Grouting	m	34,600	43	31	12	1,487,800	1,072,600	415,200
	Others	10%					4,192,745	2,437,142	1,755,603
	Sub-total						**46,120,194**	**26,808,561**	**19,311,633**
2.2	Surge Tank								
	Open Excavation	m^3	3,000	11	5	6	33,000	15,000	18,000
	Shaft Excavation	m^3	40,000	94	68	26	3,760,000	2,720,000	1,040,000
	Shotcrete 5cm	m^2	8,200	32	18	14	262,400	147,600	114,800
	Rock Bolt (D25) 5m length	nos	770	34	28	6	26,180	21,560	4,620
	Rock Bolt (D25) 2m length	nos	410	49	40	9	20,090	16,400	3,690
	Concrete, Structure	m^3	9,000	118	59	59	1,062,000	531,000	531,000
	Re-bar	ton	360	1,498	206	1,292	539,280	74,160	465,120
	Grouting	m	4,150	43	31	12	178,450	128,650	49,800
	Others	10%					588,140	365,437	222,703
	Sub-total						**6,469,540**	**4,019,807**	**2,449,733**
2.3	Penstock								
	Open Excavation	m^3	18,800	11	5	6	206,800	94,000	112,800
	Tunnel Excavation	m^3	22,900	109	81	28	2,496,100	1,854,900	641,200
	Shotcrete 5cm	m^2	7,300	19	13	6	138,700	94,900	43,800
	Shotcrete 10cm	m^2	400	40	28	12	16,000	11,200	4,800
	Rockbolt 2m	nos	2,640	39	32	7	102,960	84,480	18,480
	Rockbolt 3m	nos	150	50	41	9	7,500	6,150	1,350
	Steel Support	ton	20	1,813	1,543	270	36,260	30,860	5,400
	Concrete, filling	m^3	8,100	104	59	45	842,400	477,900	364,500
	Re-bar	ton	100	1,482	205	1,277	148,200	20,500	127,700
	Grouting	m	3,970	43	31	12	170,710	123,070	47,640
	Others	10%					399,492	267,489	132,003
	Sub-total						**4,565,122**	**3,065,449**	**1,499,673**
2.4	Powerhouse								
	Open Excavation (common)	m^3	9,000	5	1	4	45,000	9,000	36,000
	Open Excavation (rock)	m^3	35,000	11	5	6	385,000	175,000	210,000
	Concrete, Structure	m^3	24,300	149	55	94	3,620,700	1,336,500	2,284,200
	Re-bar	ton	2,430	1,435	166	1,269	3,487,050	403,380	3,083,670
	Building and utility works	LS	1		864,453	1,168,072	1,752,527	447,302	1,305,225
	Others	10%					929,028	237,118	691,910
	Sub-total						**10,219,305**	**2,608,300**	**7,611,005**

No.	Item	Unit	Quantity	Unit Price(US$)			Amount (US$)		
				Total	Foreign	Local	Total	Foreign	Local
2.5	Outlet								
	Open Excavation (common)	m^3	6,000	5	1	4	30,000	6,000	24,000
	Open Excavation (rock)	m^3	24,000	11	5	6	264,000	120,000	144,000
	Concrete, Structure	m^3	1,100	149	55	94	163,900	60,500	103,400
	Re-bar	ton	110	1,435	166	1,269	157,850	18,260	139,590
	Others	10%					61,575	20,476	41,099
	Sub-total						**677,325**	**225,236**	**452,089**
2.6	Miscellaneous Works	10%					**6,805,149**	**3,672,735**	**3,132,413**
	Total						**74,856,634**	**40,400,088**	**34,456,546**
3	**Hydromechanical Equipment**	LS	1				**21,966,000**	**17,721,100**	**4,244,900**
4	**Electromechanical Equipment**	LS	1				**81,480,000**	**67,900,000**	**13,580,000**
	Construction Cost **Total of Direct Cost (1 to 4)**						**181,488,963**	**126,451,744**	**55,037,219**
5	**Environmental Cost**	LS					**2,154,099**	**0**	**2,154,099**
6	**Adiministration and Engineering Fee** (1+2+3+4)×10%	10%					**18,148,896**	**12,645,174**	**5,503,722**
7	**Contingency** (1+2+3+4+5+6)×10%	10%					**20,179,196**	**13,909,692**	**6,269,504**
	Total of Indirect Cost (5 to 7)						**40,482,191**	**26,554,866**	**13,927,325**
8	**Project Construction Cost (1 to 7)**						**221,971,154**	**153,006,611**	**68,964,544**

10.3.4 Disbursement Schedule

The annual required funding (disbursement schedule) is indicated in **Table 10.3.4-1** with foreign and local currencies.

Table 10.3.4-1(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**													
1.1	Access Road	91,078	265,157									356,235	91,078	265,157
1.2	Temporary Power Supply	273,232	1,988,679									2,261,911	273,232	1,988,679
1.3	Camp and Office for CEB & Engineer	66,246	501,937									568,183	66,246	501,937
	Total	**430,556**	**2,755,773**									**3,186,329**	**430,556**	**2,755,773**
2	**Civil Works**													
2.1	Headrace Tunnel													
	Work adit													
	Tunnel Excavation	638,000	232,000									870,000	638,000	232,000
	Shotcrete 5cm	46,800	14,400									61,200	46,800	14,400
	Shotcrete 10cm	11,200	4,000									15,200	11,200	4,000
	Rock Bolt 2m	39,990	9,030									49,020	39,990	9,030
	Rock Bolt 3m	6,000	1,350									7,350	6,000	1,350
	Steel Support	35,489	6,210									41,699	35,489	6,210
	Headrace Tunnel													
	Tunnel Excavation	5,320,000	2,447,200	7,315,000	3,364,900							18,447,100	12,635,000	5,812,100
	Shotcrete 5cm	443,284	221,642	609,516	304,758							1,579,200	1,052,800	526,400
	Rock Bolt (D25) 2m	496,446	103,907	682,614	142,873							1,425,840	1,179,060	246,780
	Concrete, lining			326,000	240,619	3,912,000	2,887,429	2,608,000	1,924,952	0	0	11,899,000	6,846,000	5,053,000
	Re-bar			0	0	468,067	3,031,114	340,413	2,204,446	0	0	6,044,040	808,480	5,235,560
	Grouting			0	0	620,979	240,379	451,621	174,821	0	0	1,487,800	1,072,600	415,200
	Others	703,721	303,974	893,313	405,315	500,105	615,892	340,003	430,422	0	0	4,192,745	2,437,142	1,755,603
	Sub-total	**7,740,930**	**3,343,713**	**9,826,442**	**4,458,465**	**5,501,151**	**6,774,813**	**3,740,037**	**4,734,642**	**0**	**0**	**46,120,194**	**26,808,561**	**19,311,633**
2.2	Surge Tank													
	Open Excavation			15,000	18,000							33,000	15,000	18,000
	Shaft Excavation			2,417,778	924,444	302,222	115,556					3,760,000	2,720,000	1,040,000
	Shotcrete 5cm			131,200	102,044	16,400	12,756					262,400	147,600	114,800
	Rock Bolt (D25) 5m length			19,164	4,107	2,396	513					26,180	21,560	4,620
	Rock Bolt (D25) 2m length			14,578	3,280	1,822	410					20,090	16,400	3,690
	Concrete, Structure					354,000	354,000	177,000	177,000	0	0	1,062,000	531,000	531,000
	Re-bar					49,440	310,080	24,720	155,040	0	0	539,280	74,160	465,120
	Grouting					64,325	24,900	64,325	24,900	0	0	178,450	128,650	49,800
	Others			259,772	105,188	79,061	81,821	26,605	35,694	0	0	588,140	365,437	222,703
	Sub-total			**2,857,492**	**1,157,063**	**869,666**	**900,036**	**292,650**	**392,634**	**0**	**0**	**6,469,540**	**4,019,807**	**2,449,733**

Table 10.3.4-1(2) 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)
2.3	Penstock													
	Open Excavation	94,000	112,800									206,800	94,000	112,800
	Tunnel Excavation	1,324,929	458,000	529,971	183,200							2,496,100	1,854,900	641,200
	Shotcrete 5cm	67,786	31,286	27,114	12,514							138,700	94,900	43,800
	Shotcrete 10cm	8,000	3,429	3,200	1,371							16,000	11,200	4,800
	Rockbolt 2m	60,343	13,200	24,137	5,280							102,960	84,480	18,480
	Rockbolt 3m	4,393	964	1,757	386							7,500	6,150	1,350
	Steel Support	22,043	3,857	8,817	1,543							36,260	30,860	5,400
	Concrete, filling			0	0	328,556	250,594	149,344	113,906	0	0	842,400	477,900	364,500
	Re-bar			0	0	14,094	87,794	6,406	39,906	0	0	148,200	20,500	127,700
	Grouting					123,070	47,640					170,710	123,070	47,640
	Others	158,149	62,354	59,500	20,429	34,265	33,839	15,575	15,381	0	0	399,492	267,489	132,003
	Sub-total	**1,739,642**	**685,889**	**654,497**	**224,724**	**499,985**	**419,866**	**171,325**	**169,194**	**0**	**0**	**4,565,122**	**3,065,449**	**1,499,673**
2.4	Powerhouse													
	Open Excavation (common)	9,000	36,000									45,000	9,000	36,000
	Open Excavation (rock)	175,000	210,000									385,000	175,000	210,000
	Concrete, Structure	49,500	84,600	594,000	1,015,200	594,000	1,015,200	99,000	169,200	0	0	3,620,700	1,336,500	2,284,200
	Re-bar	14,940	114,210	179,280	1,370,520	179,280	1,370,520	29,880	228,420	0	0	3,487,050	403,380	3,083,670
	Building and utility works					378,486	1,104,421	68,816	200,804	0	0	1,752,527	447,302	1,305,225
	Others	24,844	44,481	77,328	238,572	115,177	349,014	19,770	59,842	0	0	929,028	237,118	691,910
	Sub-total	**273,284**	**489,291**	**850,608**	**2,624,292**	**1,266,943**	**3,839,155**	**217,465**	**658,266**	**0**	**0**	**10,219,305**	**2,608,300**	**7,611,005**
2.5	Outlet													
	Open Excavation (common)	1,500	6,000	4,500	18,000							30,000	6,000	24,000
	Open Excavation (rock)	30,000	36,000	90,000	108,000							264,000	120,000	144,000
	Concrete, Structure			60,500	103,400							163,900	60,500	103,400
	Re-bar			18,260	139,590							157,850	18,260	139,590
	Others	3,150	4,200	17,326	36,899							61,575	20,476	41,099
	Sub-total	**34,650**	**46,200**	**190,586**	**405,889**							**677,325**	**225,236**	**452,089**
2.6	Miscellaneous Works	**978,851**	**456,509**	**1,437,963**	**887,043**	**813,774**	**1,193,387**	**442,148**	**595,474**	**0**	**0**	**6,805,149**	**3,672,735**	**3,132,413**
	Total	**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**
	Construction Cost Total of Direct Cost (1 to 4)	**25,776,113**	**7,777,376**	**26,255,588**	**12,747,476**	**42,389,519**	**22,478,058**	**23,043,924**	**12,034,309**	**8,986,600**	**0**	**181,488,963**	**126,451,744**	**55,037,219**
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** (1+2+3+4)×10%	**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** (1+2+3+4+5+6)×10%	**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**
	Total of Indirect Cost (5 to 7)	**5,412,984**	**2,225,626**	**5,513,673**	**3,269,347**	**8,901,799**	**5,312,770**	**4,839,224**	**3,119,581**	**1,887,186**	**0**	**40,482,191**	**26,554,866**	**13,927,325**
8	**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 Poject

This section describes how to implement the Project after the completion of the Study. The Project has the following specific features which are different from other hydropower projects.

- There are plenty of existing geological information and less risk, because new structures such as the headrace tunnel and the power station are constructed adjacent to the existing structures.
- There is no restriction in terms of the reservoir operation because the intake for the expansion has been constructed during the construction stage of the existing power station.
- The maximum flood against the power station work is the discharge from the spillway of the Victoria dam, so it could be exactly estimated.

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. Furthermore the construction period shortening is expected because the necessary time for the detailed design is partially included in the construction period. Because there are projects with the said schemes financed by ODA loans, the implementation scheme financed by ODA loan is examined in this Chapter.

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 in comparison with the DB to the conventional scheme (i.e. Contractor is determined by the bid after consultants execute the detailed design), the most adequate scheme will be proposed.

10.4.1 Implementation Schedule

The implementation schedule is studied, provided that both the DB and the conventional schemes are executed under ODA finance.

(1) Common Conditions

It is estimated for 9 months to conduct the Environmental Impact Assessment procedure on condition that the procedure will be commenced immediately after the completion of the Study.

The loan procedure will be commenced so that the disclosure of information can be performed in accordance with the guideline of environmental and social considerations of the donor agency.

(2) Conventional Scheme

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 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.

The contract packages of the construction works are considered to consist of (1) preparatory work, (2) civil work, (3) hydromechanical work and (4) electromechanical work.

(3) DB Scheme

It is considered in the DB scheme that the detailed design and the construction work will be executed as one contract package under one bidding.

The implementation schedules including the necessary term for the selection of consultants and contractors is estimated based on the experience of Study Team. In either case, therefore, the completion will be at the end of 2016 as shown in **Figure 10.4.1-1**.

This is because the implementation of the conventional scheme can be accelerated in manner that ODA loan is provided to the detailed design and the construction work at the same time.

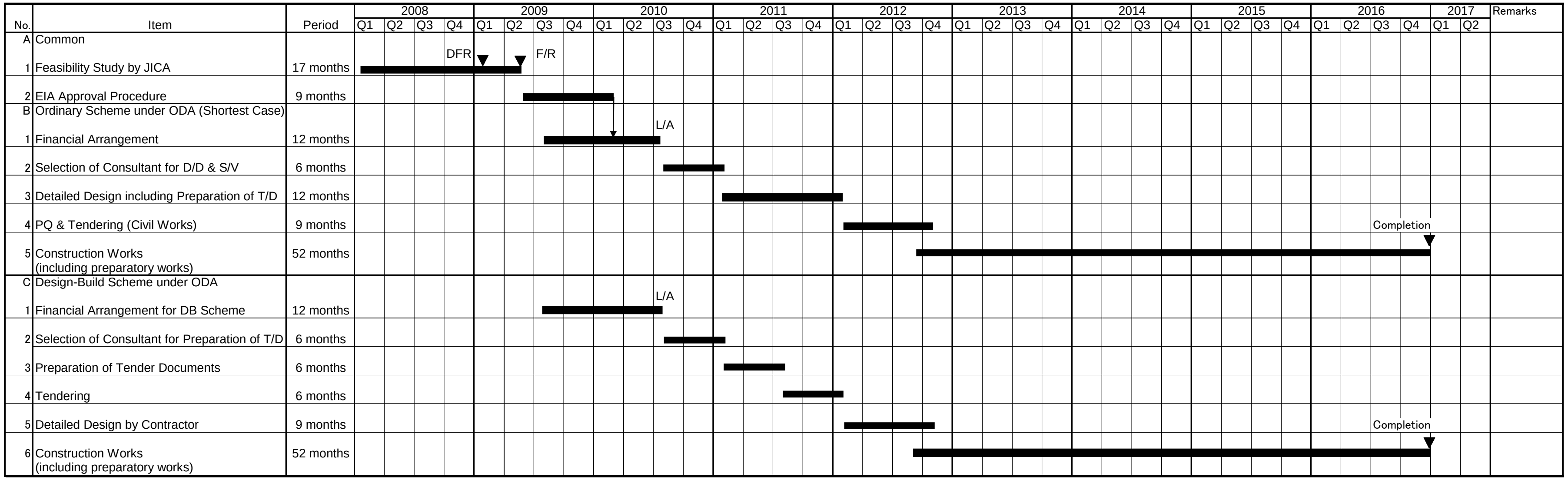


Figure 10.4.1-1 Expected Implementation Schedule for Victoria Hydropower Station Expansion Project

10.4.2 Comparison of Implementation Process

The comparison between the conventional and the DB schemes excluding the completion time is described in this section.

(1) Risk and Contract Price

In the DB scheme the Contractor is obliged to take more risks than those in the conventional scheme, such as i) risk of cost estimation without detailed design, ii) risk of cost escalation in civil work, etc.

Therefore, the bidding price of the DB scheme will be higher than that of the conventional scheme because the necessary costs for the risks mentioned above are added to the cost estimation.

(2) Contract Package

As mentioned in **10.4.1**, it is worried in the conventional scheme that the delay of the conclusion of prior contracts may affect to later contracts, because the project consists of some contract packages such as a preparation, a civil, an electromechanical and a hydromechanical contract. On the other hand, there is no risk in the DB scheme because it consists of the only one contact package.

(3) Involvement of CEB on Management for Existing Structure by Blasting Vibration

Though the Contractor shall be basically responsible for the blasting works in both schemes, the conventional scheme enables CEB (or the Engineer appointed by CED) easier to be involved in daily activities conducted by the Contractor.

(4) Security Management for CEB’s Facilities

There is no significant difference between the conventional and the DB schemes because the numbers of workers and vehicles for the construction are almost the same.

(5) Environmental and Social Considerations

There is no significant difference between the conventional and the DB schemes because the mitigation and monitoring for environmental and social considerations are the same regardless of schemes.

(6) Conclusion

Therefore, the conventional scheme is recommended because the cost estimation by the Contractor will be more reasonable due to less risk for the Contractor.

CHAPTER 11

ECONOMIC AND FINANCIAL EVALUATION

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11.1 Economic Evaluation

11.1.1 Methodology

(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.

The basic approach for this method is as follows: First, the cash outflow (costs) and inflow (benefits) are developed on an annual basis over the project life. Secondly the amount generated during different years will be discounted to the start year of the project and expressed as an accumulated present value at the same standard year. Then a comparison will be made between the costs and benefits.

Evaluation indices to be obtained will be the Net Present Value, the Benefit/Cost Ratio, and the Economic Internal Rate of Return (EIRR). The EIRR is a discount rate at which the present values of the two cash flows become equal. This rate shows the return to be expected from the project. EIRR is expressed in the following equation:

$$\sum_{t=0}^{n} C_t \,/\, (1+r)^t - \sum_{t=0}^{n} B_t \,/\, (1+r)^t = 0$$

Where,

C_t : Cost
B_t : Benefit
t : Year
n : Project life (year)
r : Discount rate (= EIRR)

(2) Basic Conditions

According to the discussions with CEB, as well as in line with the existing reports for other projects in Sri Lanka, the following basic conditions were adopted:

- Opportunity Cost of Capital
  Opportunity cost of capital refers to an interest rate at which the appropriateness of investment can be justified. A rate of 10% was used in view of the rates used for other projects in Sri Lanka.

- Discount Rate

  A discount rate of 10% will be used. This rate of 10% is also used commonly in other projects. 8% and 12% were also used for sensitivity analysis.

- Conversion Factor

  Standard conversion factor of 0.9, used commonly in other projects, was used. This is a coefficient to calculate the economic price from the construction costs estimated at the market price. It is applied to the domestic currency portion.

- Economic Life

  Economic life of each facility, according to the experience of the Consultant, was determined as follows:

  - 50 years for civil works
  - 35 years for hydro-mechanical and electro-mechanical equipment

- Project Life (Calculation Period)

  Calculation period for evaluation is 55 years: 50 years of service life of civil facilities and 5 years of construction works. It is assumed that the power plant will become commercially operational at the end of December.

- Evaluation Point

  Evaluation was made at the entrance of the Substation to which the transmission line from Victoria Hydropower Project is connected. Therefore, a transmission loss is considered.

- Cost Estimate

  Estimation of cost was based on the price level of October 2008. The work already completed as a part of existing project is considered as a sunk cost, therefore, such cost was not included in this Project.

- Escalation

  No escalation was considered, therefore, a constant price will be used.

- Tax

  Taxes including VAT are excluded from the calculation, being a transfer item.

11.1.2 Economic Costs of the Project

The economic costs of the Project were calculated from the market price as presented in **Chapter 10** (The cost includes environmental cost). Construction cost, as well as Operation and Maintenance cost and replacement cost, was included in the cost stream. The method of economic pricing is as follows:

Foreign currency portion

- Exclusion of transfer items such as taxes (import tax, value added tax) and subsidies

Local currency portion

- Exclusion of transfer items such as taxes (VAT) and subsidies

- Conversion of market prices without tax to economic price, applying standard conversion factor

(1) Initial Investment Costs (at Economic Price)

Initial investment costs by facility are shown in **Table 11.1.2-1**.

Table 11.1.2-1 Initial Investment Cost (at Economic Price)

(Unit : US$1000)

Description	1st Year		2nd Year		3rd Year		4th Year		5th Year		Total
	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	
I Direct Construction Cost											
Preparatory Works	431	2,480	0	0	0	0	0	0	0	0	2,911
Civil Works	10,767	4,519	15,818	8,782	8,952	11,815	4,864	5,895	0	0	71,411
Hydro-Mechanical Equipment	4,393	0	1,700	594	3,696	1,278	5,735	1,949	2,197	0	21,542
Electro-Mechanical Equipment	10,185	0	8,738	2,097	29,742	7,138	12,445	2,987	6,790	0	80,122
Total Direct Construction Cost	25,776	7,000	26,256	11,473	42,390	20,230	23,044	10,831	8,987	0	175,985
II Environmental Cost	0	485	0	485	0	485	0	485	0	0	1,939
III Administration and Engineering Fee	2,578	700	2,626	1,147	4,239	2,023	2,304	1,083	899	0	17,599
IV Contingency	2,835	818	2,888	1,310	4,663	2,274	2,535	1,240	989	0	19,552
Grand Total (I to IV)	31,189	9,003	31,769	14,415	51,291	25,012	27,883	13,639	10,874	0	215,075
TOTAL (FC+LC)	40,192		46,184		76,303		41,522		10,874		215,075

Conversion Factor: 0.9

Source: Study Team Calculation

The annual investment amount for major items, including the Engineering and Administration Cost as well as Contingency, is summarized in **Table 11.1.2-2**.

Table 11.1.2-2 Initial Investment Cost by Item (at Economic Price)

(unit: US$1000)

	Civil works	Hydraulic/Electro-mechanical equipment	Others	Total
1st year	15,287	14,578	10,327	40,192
2nd year	24,599	13,129	8,456	46,184
3rd year	20,766	41,854	13,683	76,303
4th year	10,759	23,116	7,647	41,522
5th year	0	8,987	1,887	10,874
Total	71,411	101,664	42,000	215,075

Source: Study Team Calculation

(2) Operation and Maintenance Cost (at Economic Price)

The Operation and Maintenance Cost is shown in **Table 11.1.2-3**. The cost was calculated by multiplying the construction cost of each work item (including a 10% contingency) by a certain rate. This rate was determined according to the experiences with similar projects by the Consultant.

Table 11.1.2-3 O&M Cost (at Economic Price)

(unit: US$1000)

Item	Construction cost	Factor	Amount
Civil Works	78,552	0.5%	393
Hydraulic/Electro-mechanical Equipment	111,830	1.5%	1,677
Total	---	---	2,070

Source: Study Team Calculation

Replacement cost of equipment after fulfilling the service life will be separately considered, referring to the initial investment cost.

11.1.3 Economic Benefit of the Project

For the purpose of the Study, an incremental benefit between the two cases: “with project” and “without project”, is considered as economic benefit for the project.

Economic benefit of a hydropower project consists of capacity benefit (kW value) and energy benefit (kWh value). Generally, the capacity benefit is obtained from incremental dependable power capacity and a capacity value assumed as a construction cost of an alternative thermal power plant, as well as fixed O&M cost; while the energy benefit is obtained from the incremental energy and energy value assumed as variable operation cost of an alternative thermal power plant (fuel cost, etc.)

After completion of the expansion works, Victoria Hydropower Project is to be operated as a 3-hour peak load power station, changing the actual operational function to cope with both peak and off-peak load power, when water is available for generation. Therefore, considering the generation characteristics for both cases of “with” and “without” the project, two alternative thermal power plants have been selected: gas turbine plant for peak load power, and coal-fired thermal power plant for off-peak load power. Power benefit and energy benefit for each alternative thermal power plant are estimated according to the following classification as shown in **Table 11.1.3-1**:

Table 11.1.3-1 Alternative Thermal Power Plant

Item	Purpose	Power Benefit	Energy Benefit
Gas Turbine	Peak load	Construction cost Fixed O&M cost	Variable O&M cost
Coal-fired Thermal	Off-peak load	---	Variable O&M cost

Source: Study Team Calculation

Economic Benefit of the Project is shown in **Table 11.1.3-2**, Economic Value of Gas Turbine in **Table 11.1.3-4** and Economic Value of Coal-fired Thermal Power Plant in **Table 11.1.3-5**. Explanation for each item follows.

Table 11.1.3-2 Economic Benefit of the Project

No.	Description	Unit	With Project	W/out Project	Net
1.	Annual Energy	GWh	715.9	705.0	11
2.	Firm Energy	GWh	468.2	230.0	238
3.	Secondary Energy	GWh	247.7	475.0	-227
4.	Dependable Peak Capacity	MW	393.0	210.0	183
5	Power to be Generated (Gas)	MW	464.7	248.3	
6	Power to be Generated (Coal)	MW	--	--	
7.	Energy to be Genereraged (Gas)	GWh/yr	479.03	235.32	
8.	Energy to be Generaged (Coal)	GWh/yr	268.03	513.98	
9.	kWh-Value (Gas)	US$/MWh	282.43	282.43	
10.	kWh-Value (Coal)	US$/MWh	63.98	63.98	
11.	kW-Value (Gas)	US$/kW	80.86	80.86	
12.	Annual Benefit (Gas)	US$1000/yr	167,069	83,441	83,627
13.	Annual Benefit (Coal)	US$1000/yr	17,149	32,885	-15,736
14.	Total Annual Benefit	US$1000/yr	184,217	116,326	**67,891**

Source: Study Team Calculation

(1) Adjustment Factor

In order to estimate the economic benefit in terms of alternative thermal power plant, firstly an adjustment factor to adjust the difference of loss rate between hydropower plant and thermal power plant is calculated. With such adjustment factor, basic characteristics of alternative thermal power plant will be obtained. Then economic benefit will be calculated using such basic characteristics. Adjustment Factor is shown in **Table 11.1.3-3**. Details for calculation are shown in **Table 11.1.3-4** and **Table 11.1.3-5**.

Table 11.1.3-3 Adjustment Factor

Item	Gas Turbine	Coal-fired Plant
kW Adjustment factor	1.18247	1.22017
kWh Adjustment factor	1.02312	1.08207

Source: Study Team Calculation

Table 11.1.3-4 Power and Energy Value of Gas Turbine Plant

A. Calculation of Power (kW) and Energy (kWh) Adjustment Factors

Item	Hydropower	Gas Turbine
Station Use	0.45% ①	2.70% ⑤
Forced Outage	0.50% ②	8.00% ⑥
Scheduled Outage	1.90% ③	8.20% ⑦
Transmission Loss	3.20% ④	3.20% ⑧
kW-Adjustment Factor	-	1.18247 ⑨
kWh-Adjustment Factor	-	1.02312 ⑩

(Note) 1. ⑨ =(1−①)∗(1−②)∗(1−③)∗(1−④)/(1−⑤)∗(1−⑥)∗(1−⑦)∗(1−⑧)

2. ⑩ =(1−①)∗(1−④)/(1−⑤)∗(1−⑧)

B. Calculation of Power Value (kW-Value)

Item	Unit	Gas Turbine
kW Construction Cost *	US$/kW	530.6 ①
Plant Life	Years	20 ②
Discount Rate	%	10.0% ③
Capital Recovery Factor		0.11746 ④
Fixed OM Cost *	US$/kW/yr	6.06 ⑤
Power Value (kW-Value)	US$/kW	80.86 ⑥

(Note) 1. ⑥ = (⑤+①∗④)∗(⑨ in above A)

2. * Economic cost based on data for 75MW Gas Turbine Plant

C. Calculation of Energy Value (kWh-Value)

Item	Unit	Gas Turbine
Fuel Type		Auto Diesel
Fuel Price *	US¢/Gcal	9,521 ①
Heat Content	kcal/kg	10,550 ②
Thermal Efficiency	%	28.10% ③
Heat Rate	kcal/kWh	2,857.0 ④
Fuel Amount	kg/kWh	0.27081 ⑤
Fuel Cost	US$/kWh	0.27202 ⑥
Variable OM Cost	US¢/kWh	0.402 ⑦
Energy Value (kWh-Value)	US$/MWh	282.43 ⑧

(Note) 1. ⑧ = (⑥+⑦/100)∗(⑩ in above A) ∗1,000

2. * US$134.15/bbl at Colombo, average from Jan. to Oct. 2008

Source: Study Team Calculation with data provided by CEB

Table 11.1.3-5 Power and Energy Value of Coal-fired Thermal Power Plant

A. Calculation of Power (kW) and Energy (kWh) Adjustment Factors

Item	Hydropower Plant	Coal-fired Thermal Power Plant
Station Use	0.45% ①	8.00% ⑤
Forced Outage	0.50% ②	11.00% ⑥
Scheduled Outage	1.90% ③	2.74% ⑦
Transmission Loss	3.20% ④	3.20% ⑧
kW-Adjustment Factor	-	1.22017 ⑨
kWh-Adjustment Factor	-	1.08207 ⑩

(Note) 1. ⑨ =(1−①)∗(1−②)∗(1−③)∗(1−④) / (1−⑤)∗(1−⑥)∗(1−⑦)∗(1−⑧)

2. ⑩ =(1−①)∗(1−④) / (1−⑤)∗(1−⑧)

B. Calculation of Power Value (kW-Value)

Item	Unit	Coal-fired Thermal Power Plant
kW Construction Cost*	US$/kW	1202.5 ①
Plant Life	Years	30 ②
Discount Rate	%	10.00% ③
Capital Recovery Factor		0.10608 ④
Fixed OM Cost	US$/kW/yr	7.73 ⑤
Power Value (kW-Value)	US$/kW	165.08 ⑥

(Note) 1. ⑥ = (⑤+①∗④)∗⑨ in above A)

2. * Economic cost based on data for 300MW Coal-fired plant

C. Calculation of Energy Value (kWh-Value)

Item	Unit	Coal-fired Thermal Power Plant
Fuel Type		Coal
Fuel Price*	US$/ton	156 ①
	US¢/Gcal	2,468
Heat Content	kcal/kg	6,300 ②
Thermal Efficiency	%	37.50% ③
Heat Rate	kcal/kWh	2,293.3 ④
Fuel Amount	kg/kWh	0.36402 ⑤
Fuel Cost	US$/kWh	0.05661 ⑥
Variable OM Cost	US¢/kWh	0.252 ⑦
Energy Value (kWh-Value)	US$/MWh	63.98 ⑧

(Note) 1. ⑧ = (⑥+⑦/100)∗(⑩ in above A) ∗1,000

2. *1 US$155.5/ton at Colombo, average from Jan. to Oct. 2008.

Source: Study Team Calculation with data provided by CEB

(2) Basic Characteristics of Alternative Thermal Power Plant

Basis characteristics of alternative thermal power plant are shown in **Table 11.1.3-6**. Detail of calculation is shown in **Table 11.1.3-2**.

Table 11.1.3-6 Basic Features of Alternative Thermal Power Plant for the Cases of "with" and "without" Project

Item	Unit	Gas Turbine		Coal-fired Plant	
	Project	with	w/out	with	w/out
Installed capacity	MW	464.7	248.3	---	---
Energy generation	GWh	479.0	235.3	268.0	514.0
Plant Life	Years	20		30	

Source: Study Team Calculation

1) Construction cost

Construction cost of alternative thermal power plant (at economic price without IDC) is shown in **Table 11.1.3-7**.

Table 11.1.3-7 Construction Cost of Alternative Thermal Power Plant

(unit: US$/kW)

	Gas Turbine (75MW)	Coal-fired (300MW)
FC Portion	460.8	889.6
LC Portion	77.6 × 0.9	347.7 × 0.9
Total	530.6	1,202.5

Source: Data from CEB (as of January 2008)

2) O&M Cost

Annual Operation and Maintenance cost (at economic price) of the alternative thermal power plant is shown in **Table 11.1.3-8**. As to Gas Turbine, foreign portion occupies 80% of the total cost, and 20% for local portion.

Table 11.1.3-8 O&M Cost for Alternative Thermal Power Plant

Item	Gas Turbine (75MW)	Coal-fired (300MW)
1. Fixed O&M cost	US$/kW/month	US$/kW/month
FC Portion	0.412	0.513
LC Portion	0.103 × 0.9	0.146 × 0.9
Total	0.505	0.644
2. Variable O&M cost	US cent/kWh	US cent/kWh
FC Portion	0.328	0.201
LC Portion	0.082 × 0.9	0.057 × 0.9
Total	0.402	0.252

Source: Data from CEB (as of January 2008)

3) Fuel Cost

Fuel cost for alternative thermal power plant is shown in **Table 11.1.3-9**.

Table 11.1.3-9 Fuel Cost of Alternative Thermal Power Plant

Item	CIF Price	Fuel Cost
Auto Diesel	US$134.2/bbl	US cent 9,521/GCal
Coal WC	US$155.5/MT	US cent 2,468/GCal

Source: Data from CEB

Based on the above-mentioned conditions, capacity and energy benefits have been estimated. Capacity benefit consists of annualized cost of Gas Turbine plant with a 10% discount rate and fixed O&M cost. Energy benefit consists of fuel cost and variable O&M cost.

11.1.4 Economic Evaluation

The total economic cost taking the present value to the initial year of the project amounts to US$182,321,000 (with a discount rate of 10%; the same will be applied to the following calculations). The total present value of the economic benefit is US$417,959,000. The net present value (B-C) is calculated as US$235,639,000, and the benefit cost ratio (B/C) was 2.29. The economic internal rate of return (EIRR) was calculated as 19.8%. (See **Table 11.1.4-2** for details.)

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% which corresponds to the opportunity cost of capital. Therefore the Project is judged as economically feasible.

Table 11.1.4-2 Economic Evaluation

(Unit: US$1000)

Year in order		Year	Cost: Construction & Replacement	Cost: Operation & Maintenance	Cost: Total	Benefit: Power Benefit	Benefit: Energy Benefit	Benefit: Total	Balance
1		2012	40,192	0	40,192	0	0	0	-40,192
2		2013	46,184	0	46,184	0	0	0	-46,184
3		2014	76,303	0	76,303	0	0	0	-76,303
4		2015	41,522	0	41,522	0	0	0	-41,522
5		2016	10,874	0	10,874	0	0	0	-10,874
6	1	2017	0	2,070	2,070	83,627	-15,736	67,891	65,821
7	2	2018	0	2,070	2,070	83,627	-15,736	67,891	65,821
8	3	2019	0	2,070	2,070	83,627	-15,736	67,891	65,821
9	4	2020	0	2,070	2,070	83,627	-15,736	67,891	65,821
10	5	2021	0	2,070	2,070	83,627	-15,736	67,891	65,821
11	6	2022	0	2,070	2,070	83,627	-15,736	67,891	65,821
12	7	2023	0	2,070	2,070	83,627	-15,736	67,891	65,821
13	8	2024	0	2,070	2,070	83,627	-15,736	67,891	65,821
14	9	2025	0	2,070	2,070	83,627	-15,736	67,891	65,821
15	10	2026	0	2,070	2,070	83,627	-15,736	67,891	65,821
16	11	2027	0	2,070	2,070	83,627	-15,736	67,891	65,821
17	12	2028	0	2,070	2,070	83,627	-15,736	67,891	65,821
18	13	2029	0	2,070	2,070	83,627	-15,736	67,891	65,821
19	14	2030	0	2,070	2,070	83,627	-15,736	67,891	65,821
20	15	2031	0	2,070	2,070	83,627	-15,736	67,891	65,821
21	16	2032	0	2,070	2,070	83,627	-15,736	67,891	65,821
22	17	2033	0	2,070	2,070	83,627	-15,736	67,891	65,821
23	18	2034	0	2,070	2,070	83,627	-15,736	67,891	65,821
24	19	2035	0	2,070	2,070	83,627	-15,736	67,891	65,821
25	20	2036	0	2,070	2,070	83,627	-15,736	67,891	65,821
26	21	2037	0	2,070	2,070	83,627	-15,736	67,891	65,821
27	22	2038	0	2,070	2,070	83,627	-15,736	67,891	65,821
28	23	2039	0	2,070	2,070	83,627	-15,736	67,891	65,821
29	24	2040	0	2,070	2,070	83,627	-15,736	67,891	65,821
30	25	2041	0	2,070	2,070	83,627	-15,736	67,891	65,821
31	26	2042	0	2,070	2,070	83,627	-15,736	67,891	65,821
32	27	2043	0	2,070	2,070	83,627	-15,736	67,891	65,821
33	28	2044	0	2,070	2,070	83,627	-15,736	67,891	65,821
34	29	2045	0	2,070	2,070	83,627	-15,736	67,891	65,821
35	30	2046	0	2,070	2,070	83,627	-15,736	67,891	65,821
36	31	2047	14,578	2,070	16,648	83,627	-15,736	67,891	51,243
37	32	2048	13,129	2,070	15,199	83,627	-15,736	67,891	52,692
38	33	2049	41,854	2,070	43,924	83,627	-15,736	67,891	23,967
39	34	2050	23,116	2,070	25,186	83,627	-15,736	67,891	42,705
40	35	2051	8,987	2,070	11,057	83,627	-15,736	67,891	56,834
41	36	2052	0	2,070	2,070	83,627	-15,736	67,891	65,821
42	37	2053	0	2,070	2,070	83,627	-15,736	67,891	65,821
43	38	2054	0	2,070	2,070	83,627	-15,736	67,891	65,821
44	39	2055	0	2,070	2,070	83,627	-15,736	67,891	65,821
45	40	2056	0	2,070	2,070	83,627	-15,736	67,891	65,821
46	41	2057	0	2,070	2,070	83,627	-15,736	67,891	65,821
47	42	2058	0	2,070	2,070	83,627	-15,736	67,891	65,821
48	43	2059	0	2,070	2,070	83,627	-15,736	67,891	65,821
49	44	2060	0	2,070	2,070	83,627	-15,736	67,891	65,821
50	45	2061	0	2,070	2,070	83,627	-15,736	67,891	65,821
51	46	2062	0	2,070	2,070	83,627	-15,736	67,891	65,821
52	47	2063	0	2,070	2,070	83,627	-15,736	67,891	65,821
53	48	2064	0	2,070	2,070	83,627	-15,736	67,891	65,821
54	49	2065	0	2,070	2,070	83,627	-15,736	67,891	65,821
55	50	2066	-58,093	2,070	-56,023	83,627	-15,736	67,891	123,914
Total			258,645	103,510	362,155	4,181,373	-786,817	3,394,556	3,032,401
Discount rate:			10%						
				PV (Cost):	182,321		PV (Benefit):	417,959	235,639
								EIRR:	**19.8%**
								NPV:	**235,639**
								B/C:	**2.29**

11.1.5 Sensitivity Analysis

(1) Conditions for Analysis

The sensitivity of economic evaluation indices was analyzed for cases with different basic conditions. A discount rate of 10% was used for this analysis. The following assumptions were made using alternative thermal cost as benefit:

Case 1 (a) 30% decrease, (b) 50% decrease in fuel cost

Case 2 (a) 10% increase, (b) 20% increase in construction cost

Case 3 50% decrease in fuel cost and 10% increase in construction cost

Case 4 1,260 MCM is tapped at the Polgolla weir (See **9.6.2** for energy calculation). Economic benefit, as well as basic characteristics of alternative thermal power plant for this case, are shown in **Table 11.1.5-1**.

Table 11.1.5-1 Economic Benefit for "with" and "without" Project for Case 4

No.	Description	Unit	With Project	W/out Project	Net
1.	Annual Energy	GWh	572.0	572.0	0
2.	Firm Energy	GWh	399.0	227.0	172
3.	Secondary Energy	GWh	173.0	346.0	-173
4.	Dependable Peak Capacity	MW	352.0	207.0	145
5	Power to be Generated (Gas)	MW	416.2	244.8	
6	Power to be Generated (Coal)	MW	--	--	
7.	Energy to be Generaged (Gas)	GWh/yr	408.23	232.25	
8.	Energy to be Generaged (Coal)	GWh/yr	187.20	374.39	
9.	kWh-Value (Gas)	US$/MWh	282.43	282.43	
10.	kWh-Value (Coal)	US$/MWh	63.98	63.98	
11.	kW-Value (Gas)	US$/kW	80.86	80.86	
12.	Annual Benefit (Gas)	US$1000/yr	143,758	82,332	61,426
13.	Annual Benefit (Coal)	US$1000/yr	11,977	23,954	-11,977
14.	Total Annual Benefit	US$1000/yr	155,735	106,286	**49,449**

Source: Study Team Calculation

Case 5 Victoria Hydropower Plant is to be operated as a base power station, due to delay in development of base power plant. (See **9.6.2** for energy calculation.) Economic benefit, as well as basic characteristics of alternative thermal power plant for this case, are shown in **Table 11.1.5-2**.

Table 11.1.5-2 Economic Benefit for "with" and "without" Project for Case 5

No.	Description	Unit	With Project	W/out Project	Net
1.	Annual Energy	GWh	730.5	709.0	22
2.	Firm Energy	GWh	172.4	135.0	37
3.	Secondary Energy	GWh	558.1	575.0	-17
4.	Dependable Peak Capacity	MW	49.0	49.0	0
5	Power to be Generated (Gas)	MW	57.9	57.9	
6	Power to be Generated (Coal)	MW	--	--	
7.	Energy to be Generaged (Gas)	GWh/yr	176.39	138.12	
8.	Energy to be Generaged (Coal)	GWh/yr	603.90	622.19	
9.	kWh-Value (Gas)	US$/MWh	282.43	282.43	
10.	kWh-Value (Coal)	US$/MWh	63.98	63.98	
11.	kW-Value (Gas)	US$/kW	80.86	80.86	
12.	Annual Benefit (Gas)	US$1000/yr	53,778	42,971	10,807
13.	Annual Benefit (Coal)	US$1000/yr	38,638	39,808	-1,170
14.	Total Annual Benefit	US$1000/yr	92,417	82,780	**9,637**

Source: Study Team Calculation

(2) Result of Sensitivity Analysis

The result of the sensitivity analysis is shown in **Table 11.1.5-3**.

Table 11.1.5-3 Result of Sensitivity Analysis

Item	NPV (US$)	B/C	EIRR (%)
Case 1a	138,192,000	1.76	16.2
Case 1b	73,226,000	1.40	13.5
Case 2a	217,407,000	2.08	18.4
Case 2b	199,175,000	1.91	17.3
Case 3	54,994,000	1.27	12.4
Case 4	122,101,000	1.67	15.5
Case 5	-122,992,000	0.33	1.6

The indices exceed the evaluation criteria for the Cases 1 to 4, and it is confirmed that, even in the worse cases, the Project is economically feasible. As the level of fuel price used for evaluation remains relatively high, EIRR continues to exceed 10% even with the 72% reduction of the fuel price (i.e. US$38/bbl for diesel and US$44/MT for coal) for the base case; and 52% reduction (i.e. US$64/bbl for diesel and US$75/MT for coal) for the Case 4. This means that the Victoria Hydropower Expansion Project is very attractive from a viewpoint of national economy to save imported fuel.

On the other hand, as evidenced with the Case 5, if delay in construction of base load power should occur and the Victoria Project would be obliged to cope with base load, its economy drastically decreases. Therefore, a key for success of Victoria Hydropower Expansion Project is to have a base load power in advance.

11.2 Financial Evaluation

11.2.1 Methodology

(1) Evaluation Method

Financial analysis aims at measuring the expected return on investment from a viewpoint of an implementing agency. Here, the Discounted Cash Flow method was adopted. The basic approach for this method is as follows: First, the cash outflow (construction cost and O&M cost estimated at market price, i.e. financial costs) and inflow (benefits as electricity sale revenue) are developed on an annual basis over the project life. Secondly the amount generated each year will be discounted to the start year of the project and expressed it as an accumulated present value at the same standard year. Then a comparison will be made between the costs and benefits. The evaluation index to be obtained is the Financial Internal Rate of Return (FIRR) on investment. FIRR on investment is not affected by financing conditions; therefore, it is appropriate to evaluate the profitability of the project itself.

(2) Basic Conditions

According to the discussions with CEB, as well as in line with the existing reports for other projects in Sri Lanka, the following basic conditions were adopted:

- Economic Life
  Economic life of each facility, according to the experience of the Consultant, was determined as follows:
  - 50 years for civil works
  - 35 years for hydro-mechanical and electro-mechanical equipment

- Project life (Calculation Period)
  Calculation period for evaluation is 55 years: 50 years of service life of civil facilities and 5 years of construction works. It is assumed that the power plant will become commercially operational at the end of December.

- Evaluation Point
  Evaluation was made at the entrance of the customers to which the energy from Victoria Hydropower Project is sent. Therefore, a transmission and distribution loss is considered.

- Cost Estimate
  Estimation of cost was based on the price level of October 2008. The work already completed as a part of existing project is considered as a sunk cost, therefore, such cost was not included in this Project.

- Escalation
  No escalation was considered, therefore, a constant price will be used.

- Tax

  Cess and PAL (Port and Airport Development Levy) of 4.5% is applied for foreign portion of the equipment. 15% import duty and 15% VAT (i.e. 32.25% in total) is applied for other foreign portion. 15% VAT is applied for local portion.

11.2.2 Financial Cost and Benefit of the Project

(1) Financial Cost

The financial cost of the Project includes the initial investment cost, the cost for replacement of equipment, and operation and maintenance cost expressed in terms of the market price including tax. The initial investment and the replacement cost were taken from the cost estimation in **Chapter 10**, adding the relevant taxes imposed in Sri Lanka. The operation and maintenance cost was calculated by multiplying the construction cost of each work item (including 10% contingency and tax) by a certain rate, which was determined based on the experiences with similar projects by the Consultant:

1) Initial Investment

Initial investment cost by major item of the Project is shown in **Table 11.2.2-1**.

Table 11.2.2-1 Initial Investment Cost by Item (at Financial Price)

(unit: US$1,000)

	Civil works	Hydraulic/Electro-mechanical equipment	Others	Total
1st year	20,015	15,234	12,607	47,856
2nd year	32,140	14,346	10,443	56,929
3rd year	26,935	45,696	15,934	88,565
4th year	13,965	25,305	8,928	48,198
5th year	0	9,391	1,972	11,363
Total	93,054	109,973	49,884	252,911

Source: Study Team Calculation

2) Operation and Maintenance Cost

Operation and Maintenance cost of the Project (including contingency) is shown in **Table 11.2.2-2**.

Table 11.2.2-2 O&M Cost (at Financial Price)

(unit: US$1000)

Item	Construction cost	Factor	Amount
Civil works and others	102,360	0.5%	512
Hydraulic and Electro-mechanical Equipment	120,970	1.5%	1,815
Total	---	---	2,326

Source: Study Team Calculation

(2) Financial Benefit

The financial benefit of the Project is the revenue to be earned by the electricity sale. Here the electricity sale revenue was obtained from an average unit rate (USc12.157/kWh), multiplied by salable energy volume, as shown in **Table 11.2.2-3**.

Table 11.2.2-3 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

Conditions used for evaluation are summarized below:

- Unit electricity rate
  Average electricity rate is applied. The provisional average rate in 2008 was Rs.13.17/kWh. In order to obtain the price in terms of US dollar, an average exchange rate in 2008 (US$1 = Rs.108.3338) was used. It resulted in US$0.12157/kWh.

- Annual salable energy
  Annual salable energy is as shown in **Table 11.2.2-4**.

Table 11.2.2-4 Annual Energy for Financial Evaluation

Item	Unit	Total Energy	Energy allocation for expansion project	
			until 2018	after 2019
Energy generation	GWh	715.9	10.9	377.9
Gross loss	%	14.0	14.0	14.0
Salable energy	GWh	615.7	9.4	325.0

Note: Gross loss rate was taken from "National Demand Forecast 2007-2027" (CEB).

The annual energy shown above is based on the following assumptions:

Actually Victoria Hydropower Station is operated for 24 hours. With the completion of the expansion units, the operation pattern would be changed to cope with peak load power for a few hours a day. There will basically be no increase in available discharge for daily generation, therefore, no significant increase in total energy generation is expected, except for a small increase which will be available due to an introduction of new generating equipment with effective generation efficiency.

Under this situation, only incremental energy to be generated with the new turbines will be considered as the benefit of the expansion project until 2018, when the economic life of 35 years for equipment of existing project is completed; thereafter all the energy with the new ones will be counted as the benefit.

The reason for adopting 35-year economic life of equipment as criteria is that such approach would generate adequate amount of financial income, and that it would not give so much impact on financial operation of the existing project, from the following viewpoints:

- Civil works such as dam would continue to be used after its economic life.
- Repayment of debt for the existing project will be completed in 2009 (according to CEB annual report 2006)
- Reduced income amount for the existing project can well cover the annual expenditure, including depreciation cost, for operation and maintenance of the existing project, which amounts to Rs.612 Million in 2006. (according to Victoria Hydro Power Station Annual Report 2006)

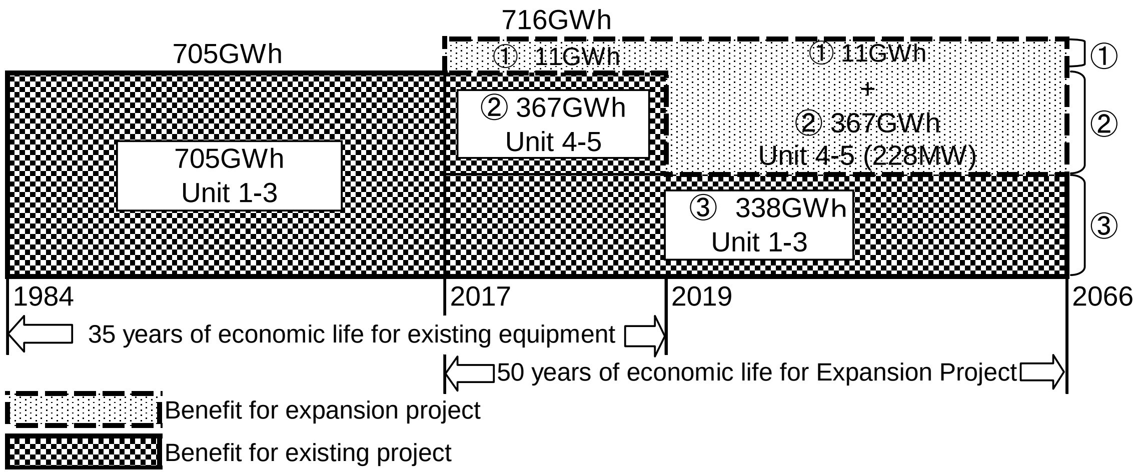

Figure 11.2.2-1 Annual Energy for Financial Evaluation

11.2.3 Financial Evaluation

The Financial Internal Rate of Return (FIRR) on investment was calculated based on the financial revenue. (See **Table 11.2.3-2.**) The result is shown in **Table 11.2.3-1**.

Table 11.2.3-1 Result of Financial Evaluation

Item	Result	Evaluation Criteria
FIRR on investment	9.6 %	> interest rate

FIRR is 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.

Table 11.2.3-2 Financial Evaluation

(Unit: US$1000)

Year in order		Year	Cost: Construction and Replacement	Cost: Operation and Maintenance	Cost: Total	Benefit: Annual Energy (GWh)	Benefit: Unit Rate (US$/kWh)	Benefit: Total Revenue	Balance
1		2012	47,856	0	47,856	0.0	0.12157	0	-47,856
2		2013	56,929	0	56,929	0.0	0.12157	0	-56,929
3		2014	88,565	0	88,565	0.0	0.12157	0	-88,565
4		2015	48,198	0	48,198	0.0	0.12157	0	-48,198
5		2016	11,363	0	11,363	0.0	0.12157	0	-11,363
6	1	2017		2,326	2,326	9.4	0.12157	1,143	-1,184
7	2	2018		2,326	2,326	9.4	0.12157	1,143	-1,184
8	3	2019		2,326	2,326	325.0	0.12157	39,510	37,184
9	4	2020		2,326	2,326	325.0	0.12157	39,510	37,184
10	5	2021		2,326	2,326	325.0	0.12157	39,510	37,184
11	6	2022		2,326	2,326	325.0	0.12157	39,510	37,184
12	7	2023		2,326	2,326	325.0	0.12157	39,510	37,184
13	8	2024		2,326	2,326	325.0	0.12157	39,510	37,184
14	9	2025		2,326	2,326	325.0	0.12157	39,510	37,184
15	10	2026		2,326	2,326	325.0	0.12157	39,510	37,184
16	11	2027		2,326	2,326	325.0	0.12157	39,510	37,184
17	12	2028		2,326	2,326	325.0	0.12157	39,510	37,184
18	13	2029		2,326	2,326	325.0	0.12157	39,510	37,184
19	14	2030		2,326	2,326	325.0	0.12157	39,510	37,184
20	15	2031		2,326	2,326	325.0	0.12157	39,510	37,184
21	16	2032		2,326	2,326	325.0	0.12157	39,510	37,184
22	17	2033		2,326	2,326	325.0	0.12157	39,510	37,184
23	18	2034		2,326	2,326	325.0	0.12157	39,510	37,184
24	19	2035		2,326	2,326	325.0	0.12157	39,510	37,184
25	20	2036		2,326	2,326	325.0	0.12157	39,510	37,184
26	21	2037		2,326	2,326	325.0	0.12157	39,510	37,184
27	22	2038		2,326	2,326	325.0	0.12157	39,510	37,184
28	23	2039		2,326	2,326	325.0	0.12157	39,510	37,184
29	24	2040		2,326	2,326	325.0	0.12157	39,510	37,184
30	25	2041		2,326	2,326	325.0	0.12157	39,510	37,184
31	26	2042		2,326	2,326	325.0	0.12157	39,510	37,184
32	27	2043		2,326	2,326	325.0	0.12157	39,510	37,184
33	28	2044		2,326	2,326	325.0	0.12157	39,510	37,184
34	29	2045		2,326	2,326	325.0	0.12157	39,510	37,184
35	30	2046		2,326	2,326	325.0	0.12157	39,510	37,184
36	31	2047		2,326	2,326	325.0	0.12157	39,510	37,184
37	32	2048	14,346	2,326	16,673	325.0	0.12157	39,510	22,838
38	33	2049	45,696	2,326	48,022	325.0	0.12157	39,510	-8,512
39	34	2050	25,305	2,326	27,631	325.0	0.12157	39,510	11,879
40	35	2051	9,391	2,326	11,717	325.0	0.12157	39,510	27,793
41	36	2052		2,326	2,326	325.0	0.12157	39,510	37,184
42	37	2053		2,326	2,326	325.0	0.12157	39,510	37,184
43	38	2054		2,326	2,326	325.0	0.12157	39,510	37,184
44	39	2055		2,326	2,326	325.0	0.12157	39,510	37,184
45	40	2056		2,326	2,326	325.0	0.12157	39,510	37,184
46	41	2057		2,326	2,326	325.0	0.12157	39,510	37,184
47	42	2058		2,326	2,326	325.0	0.12157	39,510	37,184
48	43	2059		2,326	2,326	325.0	0.12157	39,510	37,184
49	44	2060		2,326	2,326	325.0	0.12157	39,510	37,184
50	45	2061		2,326	2,326	325.0	0.12157	39,510	37,184
51	46	2062		2,326	2,326	325.0	0.12157	39,510	37,184
52	47	2063		2,326	2,326	325.0	0.12157	39,510	37,184
53	48	2064		2,326	2,326	325.0	0.12157	39,510	37,184
54	49	2065		2,326	2,326	325.0	0.12157	39,510	37,184
55	50	2066	-48,770	2,326	-46,444	325.0	0.12157	39,510	85,954
Total			298,880	116,317	415,197	15,618.8		1,898,778	1,483,581

FIRR:	9.6%

11.2.4 Sensitivity Analysis

(1) Conditions for Analysis

Sensitivity was analyzed for the cases with different basic conditions. The following cases were examined.

Case 1 (a) 10% decrease, (b) 20% decrease in annual available energy
Case 2 10% increase in construction cost
Case 3 10% decrease in annual available energy and 10% increase in construction cost
Case 4 (a) 10% increase, (b) 15% increase in electricity tariff
Case 5 10% decrease in annual available energy and 10% increase in construction cost
Case 6 Change in economic life of existing project: (a) 40 years, (b) 45 years, (c) 50 years

(2) Result of Analysis

The result of sensitivity analysis is shown in **Table 11.2.4-1**.

Table 11.2.4-1 Result of Sensitivity Analysis

Case	1a	1b	2	3	4a	4b	5	6a	6b	6c
FIRR (%)	7.2	4.9	8.8	6.5	10.3	10.7	6.5	7.0	5.5	4.4

Results of the analysis show that FIRR varies between 4.4% and 10.7% : and there is no item that presents particular sensitivity to a change in conditions. It is confirmed that the Project has financial feasibility on the condition that a soft loan such as Japanese Yen Credit is applied.

11.3 Cash Flow Analysis

In this section, a cash flow analysis was conducted considering the financing conditions.

11.3.1 Assumptions for Analysis

In order to implement the Victoria Hydropower Expansion Project, it is assumed that the project would be developed by CEB. The following assumptions were established for analysis:

1) Price level : As of October 2008
2) Construction period : 5 years (commissioning at the end of December 2016)
3) Escalation : not considered (constant price)
4) Taxes : 35% income tax; 15% import tax (4.5% for equipment); 15% VAT
5) Electricity tariff : US$0.12157/kWh
6) Evaluation period : 30 years after commissioning
7) Depreciation : Straight line method
8) Annual energy sale : 9.4GWh; 325GWh
9) O&M cost : US$2,326,000/year
10) Interest rate : 1.4% for foreign portion; 20.0% for local portion

11) Repayment period : 40 years (including 10 year grace period) for foreign portion
20 years (including 5 year grace period) for local portion

12) Commitment charge : 0.1% for unused foreign portion

11.3.2 Evaluation for Cash Flow Analysis

(1) Evaluation Method

Evaluation indices of Debt Service Coverage Ratio and Loan Life Coverage Ratio were calculated to evaluate the cash flow. **Table 11.2.3-1** shows summary and **Table 11.2.3-2** shows cash flow.

- Debt Service Coverage Ratio (DSCR)

Debt Service Coverage Ratio (DSCR) is an index that shows the coverage level of cash flow before repayment of principal and interest in each year. It assesses the creditability of a project from the viewpoint of loan repayment each year.

$$DSCR = \frac{\text{(Annual Cashflow before Repayment of Principal and Interest)}}{\text{(Annual Amount of Repayment and Interest)}}$$

Criteria: DSCR > 1.0 (However, Multilateral Financial Institutions such as the World Bank recommend that the DSCR be higher than 1.5 for financing a project.)

- Loan Life Coverage Ratio (LLCR)

Loan Life Coverage Ratio (LLCR) is an index that shows the coverage level of present value of cash flow before repayment of principal and interest over the total loan amount. It assesses the creditability of a project from the viewpoint of loan repayment during loan life. A discount rate to obtain present value corresponds to the interest rate for financing.

$$LLCR = \frac{\Sigma PV \text{ (Cashflow before repayment of principal and interest)}}{\text{(Total Loan Amount)}}$$

Criteria: LLCR > 1.0

Table 11.3.2-1 Cash Flow Analysis: Summary

1. Project Cost

Construction cost		252,911	thousand US$
- Loan	100%	252,911	thousand US$
- Equity	0%	0	

2. Financial Condition

1) Foreign finance	75%	189,683	thousand US$
- Interest rate	1.4%		
- Repayment period	30	years	
- Grace period	10	years	
- Commitment charge	0.1%	for unused portion	
2) Local finance	25%	63,228	thousand US$
- Interest rate	20.0%		
- Repayment period	20	years	
- Grace period	5	years	

3, Other Conditions

1) Interest during construction — Treated as Deferred Assets
Capitalized for five years from commissioning
10,233 thousand US$

2) Depreciation	Service life	Annual amount
- Civil works	50 years	1,861 thousand US$
- Hydromechanical equipment	35 years	669 thousand US$
- Electromechanical equipment	35 years	2,474 thousand US$

3) Weighted average interest rate 6.1%

4) Electricity tariff 0.12157 US$/kWh

	before 2018	after 2019
5) Annual available energy	10.9 GWh	377.9 GWh
6) Gross loss rate	14%	14%
7) Annual salable energy	9.4 GWh	325 GWh

8) Operation and maintenance cost 2,326 thousand US$

Debt Service Coverage Ratio (Average)	**1.92**
Loan Life Coverage Ratio	**1.31**

Table 11.3.2-2 Cash Flow Analysis: DSCR & LLCR

(Unit: US$1000)

Year in order		Year	Financial Flow: Capital Investment Fund	Foreign Fund: Principal Payment	Foreign Fund: Interest*1	Local Fund: Principal Payment	Local Fund: Interest	Profit & Loss Flow: Sales Revenue	Expense: O&M	Expense: Depre-ciation*2	Expense: Interest	Income before Tax	Income Tax*3	Income after Tax	Cash Flow: Revenue	Expense: O&M	Expense: Tax	Debt Service: Principal	Debt Service: Interest	Net Cash Flow	Debt Service Coverage Ratio
1		2012	47,856		656		2,393												3,049	(3,049)	
2		2013	56,929		1,211		5,239												6,451	(6,451)	
3		2014	88,565		2,075		9,667												11,742	(11,742)	
4		2015	48,198		2,545		12,077												14,622	(14,622)	
5		2016	11,363		2,656		12,646												15,301	(15,301)	
6	1	2017			2,656	4,215	11,803	1,143	2,326	15,236	14,458	-30,878	0	-30,878	1,143	2,326	0	4,215	14,458	-19,857	-0.063
7	2	2018			2,656	4,215	10,959	1,143	2,326	15,236	13,615	-30,035	0	-30,035	1,143	2,326	0	4,215	13,615	-19,014	-0.066
8	3	2019			2,656	4,215	10,116	39,510	2,326	15,236	12,772	9,175	0	9,175	39,510	2,326	0	4,215	12,772	20,196	2.189
9	4	2020			2,656	4,215	9,273	39,510	2,326	15,236	11,929	10,018	0	10,018	39,510	2,326	0	4,215	11,929	21,039	2.303
10	5	2021			2,656	4,215	8,430	39,510	2,326	15,236	11,086	10,861	0	10,861	39,510	2,326	0	4,215	11,086	21,883	2.430
11	6	2022		9,484	2,523	4,215	7,587	39,510	2,326	5,003	10,110	22,070	0	22,070	39,510	2,326	0	13,699	10,110	13,374	1.562
12	7	2023		9,484	2,390	4,215	6,744	39,510	2,326	5,003	9,134	23,046	4,991	18,055	39,510	2,326	4,991	13,699	9,134	9,359	1.410
13	8	2024		9,484	2,257	4,215	5,901	39,510	2,326	5,003	8,158	24,022	8,408	15,614	39,510	2,326	8,408	13,699	8,158	6,918	1.317
14	9	2025		9,484	2,124	4,215	5,058	39,510	2,326	5,003	7,183	24,998	8,749	16,249	39,510	2,326	8,749	13,699	7,183	7,552	1.362
15	10	2026		9,484	1,992	4,215	4,215	39,510	2,326	5,003	6,207	25,974	9,091	16,883	39,510	2,326	9,091	13,699	6,207	8,187	1.411
16	11	2027		9,484	1,859	4,215	3,372	39,510	2,326	5,003	5,231	26,949	9,432	17,517	39,510	2,326	9,432	13,699	5,231	8,821	1.466
17	12	2028		9,484	1,726	4,215	2,529	39,510	2,326	5,003	4,255	27,925	9,774	18,151	39,510	2,326	9,774	13,699	4,255	9,455	1.527
18	13	2029		9,484	1,593	4,215	1,686	39,510	2,326	5,003	3,279	28,901	10,115	18,786	39,510	2,326	10,115	13,699	3,279	10,090	1.594
19	14	2030		9,484	1,461	4,215	843	39,510	2,326	5,003	2,304	29,877	10,457	19,420	39,510	2,326	10,457	13,699	2,304	10,724	1.670
20	15	2031		9,484	1,328	4,215	0	39,510	2,326	5,003	1,328	30,853	10,798	20,054	39,510	2,326	10,798	13,699	1,328	11,358	1.756
21	16	2032		9,484	1,195		-843	39,510	2,326	5,003	352	31,829	11,140	20,689	39,510	2,326	11,140	9,484	352	16,208	2.648
22	17	2033		9,484	1,062			39,510	2,326	5,003	1,062	31,118	10,891	20,227	39,510	2,326	10,891	9,484	1,062	15,746	2.493
23	18	2034		9,484	929			39,510	2,326	5,003	929	31,251	10,938	20,313	39,510	2,326	10,938	9,484	929	15,832	2.520
24	19	2035		9,484	797			39,510	2,326	5,003	797	31,384	10,984	20,400	39,510	2,326	10,984	9,484	797	15,919	2.548
25	20	2036		9,484	664			39,510	2,326	5,003	664	31,517	11,031	20,486	39,510	2,326	11,031	9,484	664	16,005	2.577
26	21	2037		9,484	531			39,510	2,326	5,003	531	31,650	11,077	20,572	39,510	2,326	11,077	9,484	531	16,091	2.607
27	22	2038		9,484	398			39,510	2,326	5,003	398	31,782	11,124	20,659	39,510	2,326	11,124	9,484	398	16,178	2.637
28	23	2039		9,484	266			39,510	2,326	5,003	266	31,915	11,170	20,745	39,510	2,326	11,170	9,484	266	16,264	2.668
29	24	2040		9,484	133			39,510	2,326	5,003	133	32,048	11,217	20,831	39,510	2,326	11,217	9,484	133	16,350	2.700
30	25	2041		9,484	0			39,510	2,326	5,003	0	32,181	11,263	20,917	39,510	2,326	11,263	9,484	0	16,436	2.733
31	26	2042						39,510	2,326	5,003		32,181	11,263	20,917	39,510	2,326	11,263			25,921	
32	27	2043						39,510	2,326	5,003		32,181	11,263	20,917	39,510	2,326	11,263			25,921	
33	28	2044						39,510	2,326	5,003		32,181	11,263	20,917	39,510	2,326	11,263			25,921	
															Average DSCR (Debt Service Coverage Ratio):						1.920
		Total	252,911	189,683	47,649	63,228	129,698								Loan Life Debt Service Coverage Ratio (LLCR)*4:						**1.314**

Note:
*1 Interest for foreign fund includes commitment charge of 0.1% for unused loan.
*2 Interest during construction was capitalised in deferred assets and amortised it during five years after commissioning.
*3 Imposed 35% of income tax on net profit which subtracted net deficits if the project entity has net deficits during the nearest past five years.
*4 Discounted at 1.1% of weighted average interest rate.

(2) Result of Calculation

The result of the calculation is shown in **Table 11.3.2-3**.

Table 11.3.2-3 Result of Cash Flow Analysis

Foreign rate	1.4%	1.4%	1.4%	1.4%	5%	5%	10%
Domestic rate	20%	15%	10%	0%	10%	20%	0%
DSCR	1.92	1.97	2.03	2.23	1.71	1.66	1.50
LLCR	1.31	1.47	1.66	2.19	1.33	1.08	1.23

As a result, it has been confirmed that there is no problem in debt service in case of utilizing a Japanese Yen Credit (interest 1.4%) for foreign portion and 20% interest loan for local portion.

(3) Sensitivity analysis

Sensitivity analysis was made to confirm the change in major assumptions.

1) Increase of Construction Cost

The case with 10% increase of construction cost is shown in **Table 11.3.2-4**.

Table 11.3.2-4 Result of Sensitivity Analysis (1)

Foreign rate	1.4%	1.4%	1.4%	1.4%	5%	5%	10%
Domestic rate	20%	15%	10%	0%	10%	20%	0%
DSCR	1.75	1.79	1.85	2.02	1.56	1.52	1.37
LLCR	1.20	1.34	1.51	1.98	1.22	0.99	1.13

2) Change in Economic Life of the Existing Project

The case with change in economic life of the existing project from 35 to 50 years is shown in **Table 11.3.2-5**.

Table 11.3.2-5 Result of Sensitivity Analysis (2)

Foreign rate	1.4%	1.4%	1.4%	1.4%	5%	5%	10%
Domestic rate	20%	15%	10%	0%	10%	20%	0%
DSCR	1.15	1.14	1.08	0.97	1.04	1.04	0.93
LLCR	0.32	0.41	0.52	0.83	0.31	0.17	0.23
Internal subsidy*	17	14	10	3	18	25	21

**Annual amount required to make both DSCR and LLCR over 1. (unit: million US dollar)*

In this condition, it is found that there is no case in which both DSCR and LLCR exceed 1.00. Therefore, annual amount required to make these values over 1.00 has also been calculated. Such amount should be compensated in any form for 17 years to complete 50 years of economic life for the existing project.

11.3.3 General Evaluation

Victoria Hydropower Expansion Project has high economic profitability, and its implementation is judged to be useful from a viewpoint of national economy. In this project, the financial index varies largely depending on the method of estimation of financial income or benefit.

Basic pre-condition applied was to consider the project life of the existing project being 35 years which correspond to that of equipment, and the electricity generation by additional generators thereafter was taken as benefit for the expansion project. In this case the project would have sound debt service capacity.

On the other hand, as examined in the sensitivity analysis, in case of changing the pre-conditions towards the worse case as to decrease the financial income, evaluation indices show negative result for sound debt service. In such a case, in order to implement the expansion project, the deficit amount shall be compensated by income from other projects, so as to make the project feasible. It is most probable that such compensation shall be made by the existing Victoria Hydropower Project. This is because the expansion project shall operate the same reservoir jointly with the existing one so as to obtain the maximum benefit as a whole complex, therefore, the use of a part of income from the existing project may be justifiable in CEB to compensate deficit in debt service, if any.

The conditions for implementation of the Project are reiterated here:

1) Implementation of thermal power projects to cope with the base load as scheduled.
2) Use of a soft loan with favorable conditions.
3) Provisions to secure the financial income for sound debt service.

CHAPTER 12

SUGGESTIONS TO IMPLEMENT THE PROJECT

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The 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 items to consider during the period after completion of the Study up to the commencement of implementation of the Project which has the above advantages are mentioned in this chapter. **Section 12.1** describes the matters to be confirmed before implementation of the Project, **Section 12.2** mentions the items to consider for CDM application, **Section 12.3** proposes investigations and design for the Project after the Study, and **Section 12.4** proposes a monitoring plan on water table variation, respectively.

12.1 Matters to Be Confirmed before Implementation of the Project

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

- Development schedule on new power sources for base demand up to 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 financed by the World Bank as described in **Chapter 5**.

Confirmation of the above two matters is indispensable from the viewpoint of finance evaluation of the Project as mentioned in **Chapter 11**. Those described in the previous chapters are summarized in this section, and Study Team’s suggestions are mentioned.

12.1.1 Confirmation of Supply-Demand Balance of Base Demand

The Study has been conducted based on the condition that the Victoria Hydropower Station, which functions power sources for base demand in addition to those for peak demand, will be used for power sources for peak demand after expansion as mentioned repeatedly in pervious chapters. For the reason, it is necessary for new power sources to be developed for meeting base demand, in order that the Victoria Hydropower Station can change its role from base power sources to peak power sources.

In **4.2.2**, the development schedule on new base power sources has been checked, and supply capacity for base demand in the commissioning year of the expansion has been reviewed. Namely, necessary capacity of new base power sources has been estimated based on the CEB’s power demand forecast (see **4.1.4**) which is the latest as of February 2009. Consequently, it is confirmed that a new 300 MW thermal power plant as base power source will be required in 2016, the commissioning year of the Project, in addition to the existing thermal power plants, the Kerawalapitiya Combined Cycle Power Plant (270 MW) and Puttalam Stage I (285 MW).

It is necessary to confirm, before project implementation, that base demand in the commissioning year will be satisfied with new and existing power sources, based on the CEB's power demand forecast and power expansion plan.

12.1.2 Confirmation of Review Result of Water-Use Plan on the Mahaweli River

The DSWRPP is being undertaken under finance by the World Bank. The water-use plan on the Mahaweli river is to be reviewed in the DSWRPP, as mentioned in **5.3**, and there is a possibility to change the diversion policy at the Polgolla weir and irrigation demands in the downstream areas of the Victoria dam. The review is scheduled to be completed in April 2011, 2 years after the contract signing with a consultant, in accordance with information in February 2009, although the DSWRPP continues for 4 years. Hence, it is required to confirm the new annual diversion policy at the Polgolla weir and the irrigation demands of the downstream areas, after its result is obtained.

If one of them or both is changed from the present policies, a revision of the basic design or both optimization study and basic design may be required.

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. Items to consider for CDM application are mentioned in this section, although the application has not been examined in the Study.

(1) Expiry of Kyoto Protocol

The Kyoto Protocol (1997) will expire in 2012. Because the Project is commissioned in 2016, it is necessary to investigate new rules stipulated in a new protocol and to decide whether or not CDM will be applied to the Project based on the new rules.

(2) Project Financed by ODA Loan

The Project is expected to be implemented under ODA as mentioned in **11.2**. Meanwhile, the Marrakesh Accords which decided general rules for CDM stipulates "public fund for CDM projects is not in the diversion of ODA". There, however, are ODA projects approved as CDM projects, in the case that the government providing the ODA loan confirmed in writing that "public fund for CDM projects is not in the diversion of ODA". Hence, if CEB has an intention to apply CDM to the Project, CEB will need to discuss with the donor agency whether or not to do so.

(3) Commencement of Exanimation on CDM Application

In accordance with rules by the CDM Executive Board, it is difficult to obtain an approval for application for CDM, if an examination on CDM application is commenced after the commencement of the construction works of a project. CEB, therefore, will have to decide whether or not to apply CDM to the Project by the commencement of the construction works, and to officially record the commencement date of their examination on CDM.

(4) Quantitative Verification for Reduction of Greenhouse Gas

It should be quantitatively verified that exhausted greenhouse gas (GHG) can be reduced by implementing a project in comparison with “without project” status. In the case of the Project, a generation type of an alternative power plant (for example additional generation of the existing diesel power plant, etc.) in “without project” status will be firstly decided, and difference, in a form of GHG volume, between CO_2 volume exhausted by the alternative power plant and that exhausted by the Victoria Hydropower Station after expansion will be estimated.

Hence, it is necessary to decide a generation type of the alternative power plant and to examine whether or not to be able to quantitatively verify reduction volume of GHG in earlier stage of the examination for CDM.

12.3 Proposal on Investigations and Design

The necessary investigations in the detailed design, etc. in succession to the Study are proposed as follows.

12.3.1 Geological Investigations

The geological conditions surrounding the main structures proposed in the Study should be investigated particularly during the detailed design stage. Items to be investigated are proposed as below.

(1) Route of Waterway

1) Headrace Tunnel

The risks of geology would be limited because the new headrace tunnel is to be constructed adjacent to the existing one, and the records of the existing construction works would be useful for construction of the new headrace tunnel. However the observation holes are expected to be installed in order to monitor the groundwater level which may be temporarily lowered during the construction of the new tunnel. The monitoring shall be executed from at least 1 year before the commencement of the headrace tunnel excavation works up to at least 1 year after the completion, in order to confirm the fluctuation of groundwater level before the commencement of works, during the construction period, and in a period of the recovery after the completion. The observation holes should be installed in the areas where the earth covering of the tunnel is thin or in the distributional area of quartzite.

A recommended monitoring plan on groundwater level is mentioned in **12.4**.

2) Surge Tank and Penstock Tunnel

The drilling investigation is needed for confirming geology around the surge tank. The water permeability test is also recommended for confirming whether or not pervious layers are located so that the preventive measures for waterproof during the construction period can be decided, because there are some water wells for local residents around the surge tank.

In addition, the deforming characteristic of rock surrounding the penstock tunnel should be evaluated with loading test using boreholes so that the sharing ratio of internal pressure to bedrock around the penstock tunnel can be decided.

3) Portal of Penstock Tunnel

Because portals of a tunnel are generally located in a weathering rock area where the earth covering of the tunnel is thin, careful treatment is needed in terms of the stability of slopes around the tunnel and its portal. Since Gneiss especially tends to be unstable due to the weathered rock with low-angled cracks, the distribution of weathered rock is recommended to be investigated with drilling, to corporate the results into the design of the tunnel portal and tunnel support plan near the portal.

4) Penstock in Open-air Section

Because the block anchors for the penstock in the open-air section are located in the area where the slope tends to be unstable due to the weathered rock with low-angled cracks, the distribution of weathered rock is recommended to be investigated with drilling, to corporate the results into the design of slope excavation.

(2) Powerhouse

The risks of geology would be limited because the new powerhouse is to be constructed adjacent to the existing one, and the records of the existing construction works would be utilized. Besides, as the phenomenon of the landslide is not observed, further investigations may not be necessary. However the shape of excavation at the existing powerhouse is uncertain because it is already backfilled, therefore, the confirmation is needed during the construction stage.

(3) Material Investigations

The alteration of land for the concrete aggregates is planned to be minimized because the project site is designated as the environmental conservation area. Hence, mucks from the waterway tunnel and the surge tank will be processed into fine and coarse aggregates with the crushing plant according to the actual performance of Upper Kotmale Hydropower Project.

However concrete aggregate testing of basement rocks is recommended to be executed because the mechanical characteristics of rocks may be different from those of Upper Kotmale site. The items of concrete aggregate testing are proposed to be for specific gravity, water absorption ratio, stability, abrasion, alkali-aggregate reactivity.

The fine aggregates may also be obtained from river bed of the Victoria reservoir as mentioned in Chapter **10**, to keep quality of fine aggregates and to produce them at reasonable cost. After obtaining permission for using the area as sand quarry, the above mentioned aggregate tests are recommended to confirm qualities of the sands.

12.3.2 Environmental Investigations

(1) Investigation into Private Residences surrounding the Construction Site

The conditions of private residences (cracks of walls etc.) which are likely to be affected by the blasting are recommended to be investigated and recorded prior to the construction works.

(2) Survey on Elephants

It is necessary to conduct survey on habitat of elephants along the Mahaweli river from the existing powerhouse area up to the Randenigala reservoir. Eight sets of CCTV (Closed Circuit Television) cameras should be installed on the right bank in regular intervals to survey the elephants on the river bed. The survey and analysis should be conducted by DWLC and the expert of animal ecology.

12.3.3 Items on Design

(1) Waterway

The current conditions of the existing structures such as the completed intake, the headrace (until Ch.150 m) and the existing work adit are recommended to be surveyed, to corporate their result into the detailed design.

(2) Powerhouse

Because coordinates of only one point in the existing powerhouse is indicated in the drawings kept by CEB. Hence, detailed survey of the existing powerhouse is necessary to corporate its results into the detailed design.

12.3.4 Investigations for Existing Structures

Construction works of the Project will have to be performed with careful attentions to the existing structures so as to avoid them from damaging due to the blasting, because new structures are constructed adjacent to the existing Victoria dam, powerhouse and other facilities. Hence, it is indispensable to record the initial conditions of the existing structures immediately before the commencement of blasting.

A monitoring plan on the existing structures during the construction period is also recommended to be prepared during the detailed design stage.

Furthermore in terms of the Victoria dam, it is recommended that the above monitoring plan should be prepared in consideration of the current monitoring items observed by MASL and that values observed immediately before the commencement of blasting should be collected for baseline records of the dam.

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.

(1) Water Table in Borehole

Generally, the water in wells comes from surface reservoir such as sediment zone or weathered zone. However certain wells are recognized through the site reconnaissance that the water comes from basement rock seepages. The flow of groundwater is likely to be affected by the tunnel excavation, therefore the pore water table measurement in boreholes is recommended. The locations should be selected near the recognized wells and near the water passes in the basement rock. Recommended locations of boreholes are shown in **Figure 12.4-1 (1)** and **Figure 12.4-1 (2)**. The recommended specifications of the boreholes are shown in **Table 12.4-1**.

(2) Water Table in Well

The wells shown in **Figure 12.4-1 (1)** are considered to give valuable information on water table, because the wells did not dry up even in the dry season when the site reconnaissance was carried out. Hence, the water table measurements of all the wells are recommended. Flow measurements with V-notch are recommended for the wells of which the water overflows from the collar.

(3) Meteorological Parameter

Water supply from the surface reservoir may be influenced by current rainfalls. The measurement of meteorological parameters such as temperature, humidity and precipitation is recommended in order to analyze reasons of the water table variations, if possible. The record of the water level of Victoria reservoir which may equal to the water pressure inside the existing tunnel is also necessary to analyze the variations.

(4) Monitoring Program

Monitoring period is recommended to include the natural variation of water table before the commencement of works, temporary drawdown during the excavation stage, and the recovery after the completion of the lining concrete around the tunnel. The monitoring program is summarized in **Table 12.4-2**.

Table 12.4-1 List of Recommended Boreholes

Hole Number	Chainnage of tunnel (m)	Elevation (m)		Depth (m)	Offset from Tunnel Center (m)	Assumed Water Pass	In Situ Testing
		Collar	Bottom				
MH-1	2,250	340	245	95	30	Quartzite poor zone no.4	1) core logging 2) permeable test
MH-2	3,600	375	220	155	30	Quartzite	
MH-3	5,200	315	195	120	30	Quartzite Crystalline Limestone	

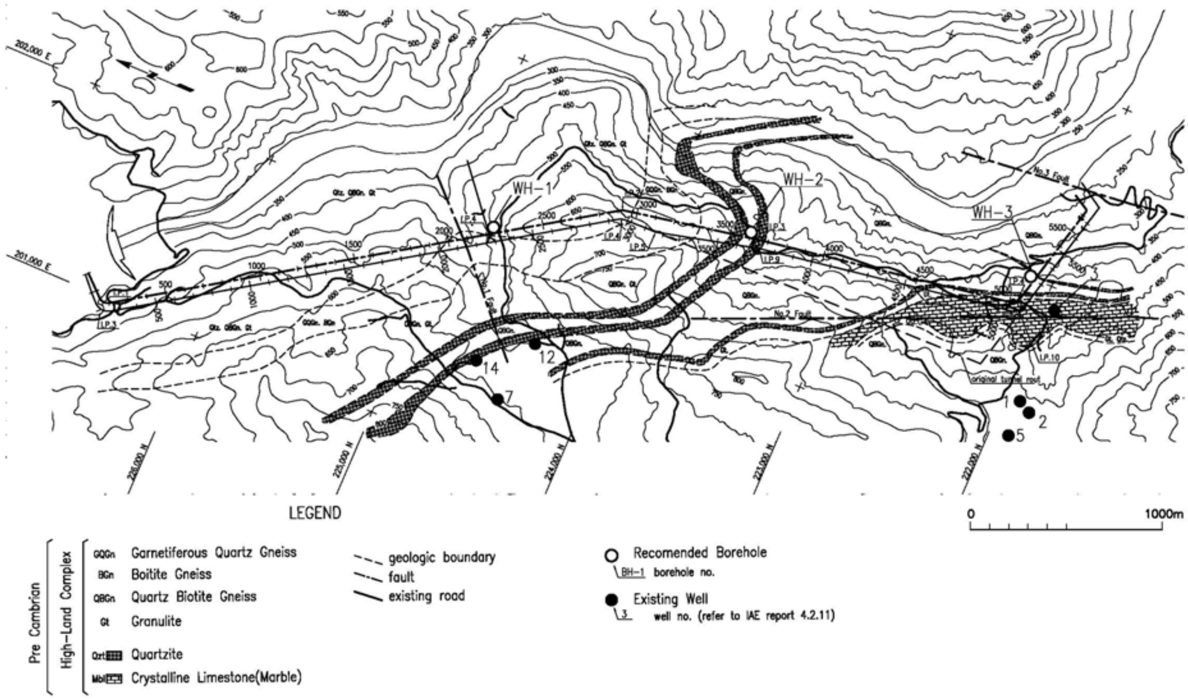

Figure 12.4-1(1) Locations of Water Table Measurements (plan)

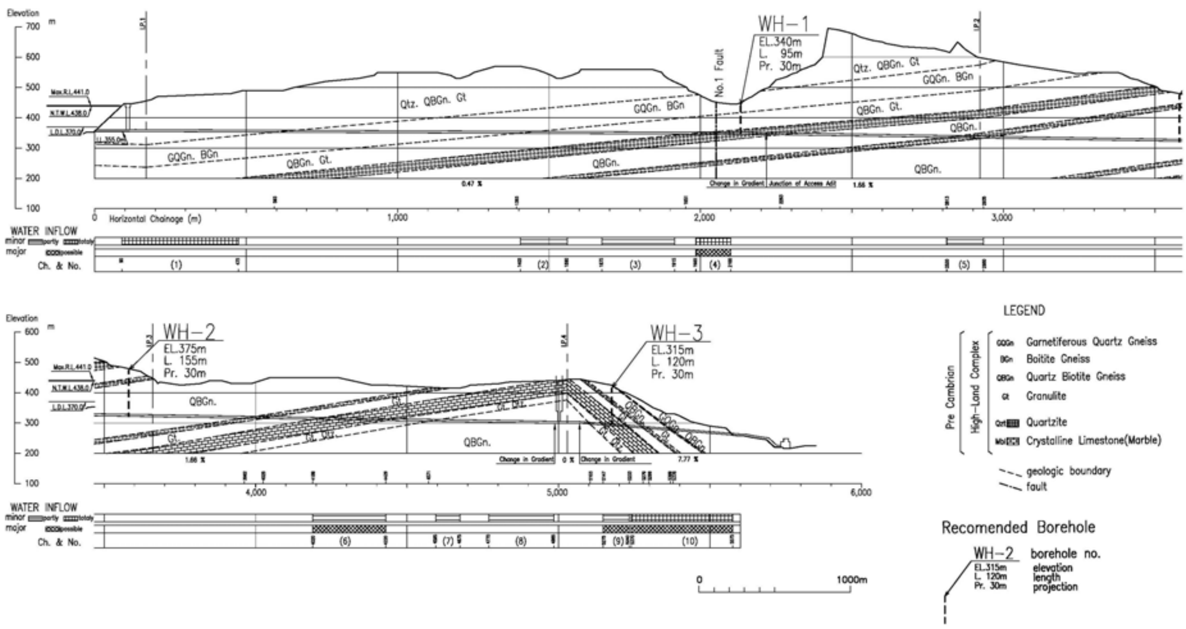

Figure 12.4-1(2) Locations of Water Table Measurements (profile)

Table 12.4-2 Water Table Monitoring Program

Object	Measurements	Duration from	Duration until	Frequency
Borehole	water levels in the bore holds using Dip Meter	at least 1 year before excavation	verification of recovery (at least 1 year after completion)	1) Before excavation: → once a week 2) During excavation: → once a day 3) After excavation: → once a week
Well (static)	water levels in well using Tape Measure or Dip Meter			
Well (overflow)	overflows of wells using V-notch			
Meteorology	thermometer, hygrometer, rain gauge			→ once a day