ISLAMIC REPUBLIC OF PAKISTAN
Water and Power Development Authority (WAPDA)

PREPARATORY SURVEY FOR MANGLA HYDRO POWER STATION REHABILITATION AND ENHANCEMENT PROJECT IN PAKISTAN

Final Report (Summary)

January 2013

JAPAN INTERNATIONAL COOPERATION AGENCY
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FINAL REPORT (SUMMARY)
for
The Preparatory Survey for Mangla Hydro Power Station Rehabilitation and Enhancement Project in Pakistan

CONTENTS

CHAPTER 1 INTRODUCTION

1.1 Background of the Survey

In the Islamic Republic of Pakistan (hereinafter referred to as “the country”), the power demand has increased at about 10.3% per annum in the past ten years along with the economic growth rate of the country. However, the power supply did not catch up with the power demand which continue to increase year after year. About 6,105 MW power supply-demand gap was recorded in the summer of 2011. Under these circumstances, the people of the country have to brace the planned power outage for about eight hours daily on the average. The planned power outage has caused difficulties in people’s lives and derailed the development of agriculture which depends on irrigation. The industries have also suffered great economic losses due to power outage causing unemployment in the country and high production cost of finished products. Therefore, the closing of the supply-demand gap in power sector is urgently required.

1.2 Objective of the Survey

1.2.1 Objective of the Survey

The Survey aimed at enhancing the maturity of the Project appropriate for Japanese ODA Loan financing and searching for the possibility of applying the Special Terms for Economic Partnership (STEP) condition to the Project.

The Survey was carried out as a supplemental survey to the feasibility study (hereinafter referred to as “the F/S”) conducted by Water and Power Development Authority of the country (hereinafter referred to as “WAPDA”) in June to December 2011.

Source: Prepared by the Survey Team

Photo 1-1 Mangla Hydro Power Station and Guest House

1.2.2 Objective Area of the Survey

The Mangla Hydro Power Station is located in Azad Jammu Kashmir, Pakistan. The power station and related dam are situated in a place called Mangla on the Jhelum River, lying in Azad Jammu and Kashmir (District Mirpur), located about 30 km upstream of Jhelum City (120 km from Capital Islamabad).

The related reservoir of the dam lies in Azad Jammu and Kashmir (AJK) and the Punjab Province (Districts Jhelum and Rawalpindi). The boundary between AJK and Punjab passes through the center of the Jhelum River. The power station and dam stand in AJK side, which lies on the left bank side of Jhelum River, and the Punjab side is located on the right bank of the river. A fairly good network of paved roads exists in and around the project area.

1.2.3 Scope of Work of the Preparatory Survey

The scope of work of the preparatory survey is as below:

(1) Field Site Survey
(2) Estimation of the Project Costs
(3) Composition of the Project Components
(4) Elaboration of Project Implementation and O&M Plan
(5) Review of Environmental and Social Consideration
(6) Confirmation of the Project Effect
(7) Draft of the Project Implementation Program and Project Status Report (PSR)

1.3 Basic Concept

(1) The Survey was stated as a supplemental to the F/S carried by WAPDA in June to December 2011.

(2) The Survey was implemented aiming to formulate the Project for STEP yen loans. The guideline published by the Ministry of Foreign Affairs of Japan stipulates the following conditions in applying for STEP yen loans:

1) Procurement Condition

<u>The borrowing country should procure the equipment manufactured in Japan which cost more than 30% of the total contract amount of the project.</u>

2) Contractor's Condition

The main contractor of the project should be a Japanese firm incorporated and registered under the laws of Japan. In case of a consortium, it should consists of a Japanese firm and a foreign firm, where the Japanese firm shall be the consortium leader.

Adding to the above, the condition cited below is applied to the Project and other project components such as hydropower generation, dam, tunnel, port and harbor, and sewer.

As for the portion of the project which is expected to utilize the Japanese superior technology during construction, the service cost shall be included in the calculation of Japanese procurement portion as well as the equipment cost.

CHAPTER 2 BASIC DATA AND INFORMATION

2.1 Power Sector's Issues

2.1.1 Annual Power Supply and Demand Gap

As of March 2012, the total installed capacity of Pakistan through all resources was around 21,527 MW. However, rapid demand growth and insufficient generation development created a gap between supply and demand resulting to significant load shedding.

Table 2-1 below shows the level of power shortage in recent years from zero power shortage in 2003 to almost 23% in 2010.

Table 2-1 Power Shortage Level between National Sale and National Demand

Year	National Sale[1] [GWh]	National Demand [GWh]	National Power Shortage [GWh]	Power Shortage Rate [%]
2003	52,661	52.661	-	0.0
2004	57,467	57,986	520	0.9
2005	61,247	61,512	265	0.4
2006	67,608	68,815	1,208	1.8
2007	71,947	73,982	2,040	2.8
2008	72,518	85,096	12,578	14.8
2009	69,668	87,890	18,222	20.7
2010	73,595	95,238	21,821	22.9
2011	89,402	115,247	25,845	22.4

Source: Power System Statistic 35th Edition and National Power Control Center

The annual power demand and supply gap which started in 2004 created a slight increase up to 2.8% in 2007. The gap then abruptly increased to 14.8% in 2008 and further increased to 22.9% in 2010.

2.1.2 Peak Generation and Peak Demand Gap

The peak demand increased rapidly at 62.6% in eight years from 2003 to 2011. On the contrary, peak generation power increased only at 7.8%, which caused a huge gap between generation and demand as shown in Table 2-2 and Figure 2-2.

During the survey conducted in May 2012, the scheduled outage of power was for 12 hours in urban areas and 18 hours in rural areas.

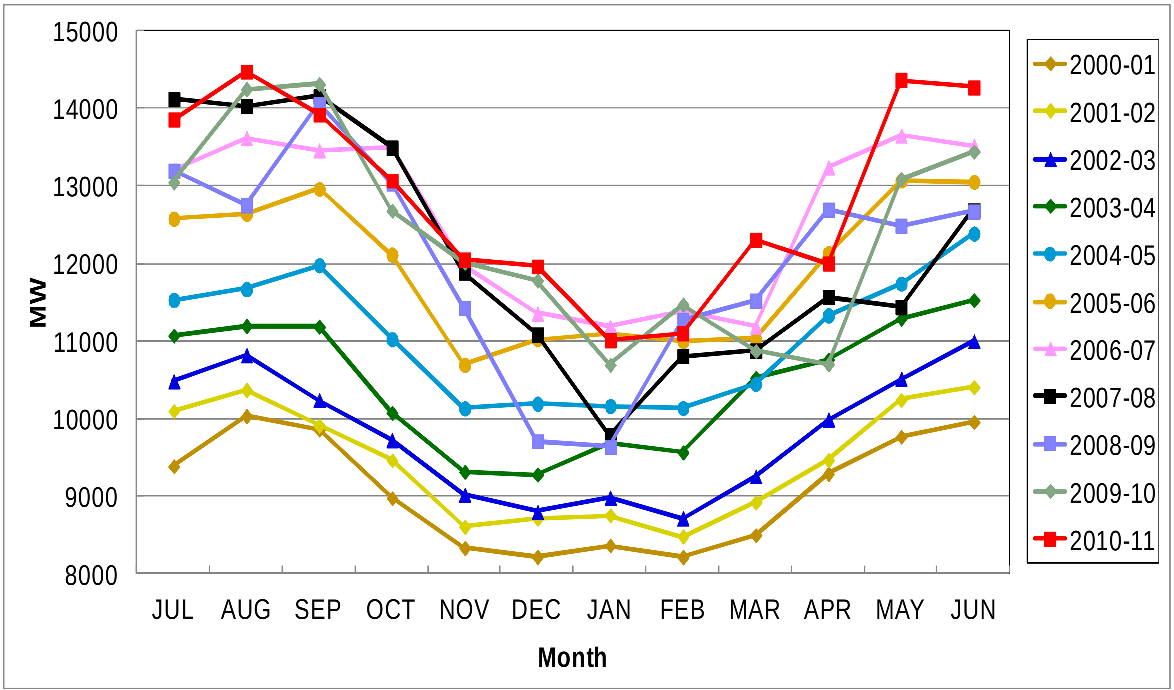
[1] Peak generation power is a maximum generating power on hourly average in the year.

Table 2-2 Power Shortage Levels between Peak Generation Power and Peak Demand

Year	Peak Generation Power [MW]	Peak Demand [MW]	Power Shortage [MW]	Power Shortage Rate [%]
2001	10,894	10,459	435	4.2
2002	10,958	11,044	86	0.8
2003	11,834	11,598	-236	-2.0
2004	12,792	12,595	-197	-1.6
2005	12,600	13,847	1,247	9.0
2006	13,292	15,838	2,546	16.1
2007	12,442	17,398	4,956	28.5
2008	13,637	17,852	4,215	23.6
2009	13,413	18,583	5,170	27.8
2010	13,163	18,521	5,358	28.9
2011	12,755	18,860	6,105	32.4

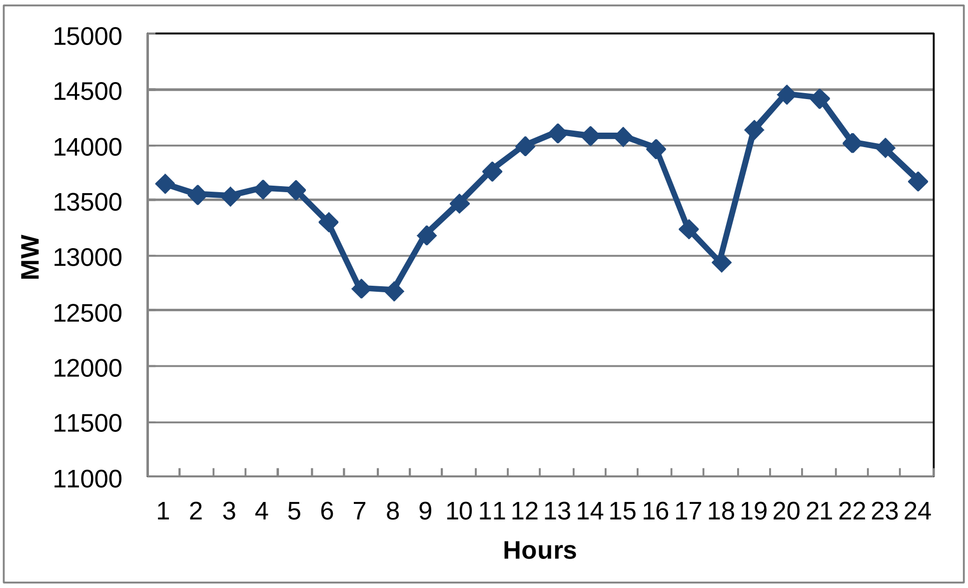
Source: Presentation Documents for Participants in the 10th SMC of National Institute of Management, Karachi

The monthly peak demand for the ten-year period from 2000 to 2010 and the load curve peak demand on August 30, 2011, which recorded the highest peak demand in 2011, are shown in Figure 2-1 and Figure 2-2 respectively.



Source: NTDC Yearly System Operation Data, 2012

Figure 2-1 Monthly Peak Demand for the Past 10 Years



Source: NTDC Yearly System Operation Data, 2012

Figure 2-2 Load Curve of Peak Demand on August 30, 2011

2.2 National Power System Expansion Plan

In order to address this gap, the National Transmission and Dispatch Company (NTDC) of Pakistan developed a National Power System Expansion Plan (NPSEP).

The objective is to provide a plan for the development of hydro-electric, thermal, nuclear, and renewable energy resources to meet the expected load up to the year 2030.

2.3 Generation Planning

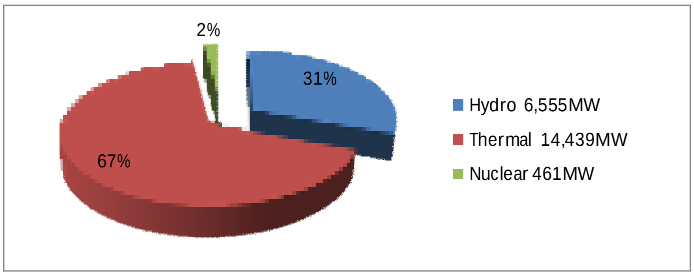
2.3.1 Existing Installed Capacity of Power Generation Plants

The total installed capacity of existing hydro and thermal generation units in the country including the Karachi Electric Supply Company (KESC) system and independent power producers (IPPs) was about 21,527 MW, as of March 2012. However, due to seasonal variation of water inflow for hydro plants and the capacity de-rating for thermal units, the dependable capacity for the systems was estimated at 15,259 MW during winter. The breakdown is shown in Table 2-3 and Figure 2-3.

Table 2-3 Summary of Existing Power Plants

Type of Plant	Owner	Installed Capacity[2] (MW) A	Capacity in Winter (MW) B	Ratio B / A
Hydro Plant	WAPDA	6,516	2,308	35.4%
	IPPs	111	111	100%
	Sub-Total Hydro	*6,627*	*2,419*	*(36.5%)*
Thermal Plant	-	-	De-rated Capacity (MW) B	-
	PEPCO	4,829	3,580	74.1%
	IPPs for PEPCO	7,475	6,909	92.4%
	Rental for PEPCO	113	113	100%
	KESCO	1,655	1,463	88,4%
	IPPs for KESCO	367	353	96.2%
	Sub-Total Thermal	*14,439*	*12,418*	*(86.0%)*
Nuclear Plant	for PEPCO	325	300	92.3%
	for KESC	136	122	89.7%
	Sub-Total Nuclear	*461*	*422*	*(91.5%)*
Total		**21,527**	**15,259**	**70.9%**

Source: National Power System Expansion Plan 2011-2030



Source: National Power System Expansion Plan 2011-2030

Figure 2-3 Installed Capacity of Power Plants

2.3.2 Existing Hydropower Plants

Existing hydropower plants (HPP), as of March 2012, are listed in Table 2-4. The installed capacity including IPP's hydropower stations was 6627 MW, as of March 2012 . However, due to the seasonal variation of inflow, the capability of generation during summer and winter seasons were 6,445 MW or 97% of installed capacity, and 2419 MW or 37% of installed capacity, respectively.

[2] The installed capacity in Table 2-13 is the total MW of operational generating plants in the country, as of March 2012.

Table 2-4 Summary of Existing Hydropower Plants

Owner	No.	Name of Power Station	Installed Capacity (MW)	Capability (MW)		
				Summer	Winter	Win/Sum
WAPDA	1	Tarbela	3,478	3,521	1,101	31.3%
	2	Ghazi Barotha	1,450	1,405	580	41.3%
	3	Mangla	1,000	1,014	409	40.3%
	4	Warsak	234	171	145	84.8%
	5	Chashma Low Head	184	91	48	52.7%
	6	Khan Khwar *1	72	68	5	7.4%
	7	Small Hydros	89	64	20	31.3 %
		Sub-Total WAPDA	6,516	6,334	2,308	*36.4%*
IPPs	8	Jagran	30	30	30	100%
	9	Malakand-III	81	81	81	*100%*
		Sub-Total IPP	111	*111*	*111*	*100%*
Total			6,627	**6,445**	**2,419**	**37.5%**

Source: National Power System Expansion Plan 2011-2030/ *1 Khan Khwar HPP, which started operation in November 2010, was added by the Survey Team based on the information given by WAPDA.

At present, Mangla HPP is the third largest hydropower station in Pakistan, which contributes 15.1% of the hydropower installed capacity.

2.3.3 Future Planning of Hydropower Plants to be commissioned by 2020

"Vision Statement for Accelerated Development of Pakistan's Power Sector for Sustained Economic Growth" at the Energy Summit held at Islamabad in May 2010. The "Vision" includes a "20,000 MW addition by 2020 programme" which targets installation of 20,000 MW of capacity in addition to the presently installed capacity. The "20,000 MW addition by 2020 programme" comprises 6,000 MW of hydro, 6,000 MW of coal (mainly by domestic production), 5,000 MW of gas, 1,000 MW of naphtha and other indigenous fuels and the remaining 2,000 MW from alternative energy resources, specifically solar and wind.

The future planning of hydropower plants to be commissioned by 2020 is shown in Table 2-5.

It is expected to be commissioned 18 hydropower plants (6,654 MW in total) by 2020.

Table 2-5 Future Planning of Hydropower Plants by 2020

Owner	Components	Installed Capacity (MW)	Expected Commissioning Year
WAPDA	Mangla Dam Raising	*644 (GWh)*	-
	Allai Khwar	121	Oct. 2012
	Duber Khwar	130	Mar. 2013
	Jinnah Barrage	96	Dec. 2012
	Satpara Dama	17.4	Feb. 2013
	Gomal Zam	17.4	Jan. 2013
	Neelum Jhelum	969	Oct. 2015
	Kurram Tangi	83	Dec. 2015
	Golen Gol Chitral	106	Feb. 2015
	Kurram Tangi – Fata	84	2015
	Tarbela 4th Extension	1,410	2017
	Kohala AJK	1,100	2020
	Dasu	2,160	2020
	Keyal Khwar	122	2018
	Phandar	80	2018
	Basho	40	2017
	Harpo	34.5	2017
	Sub-Total	*1,432*	-
IPP	New Bong Escape	84	2013-14
Total		**6,654**	-

Source: Hydel Development Department of WAPDA

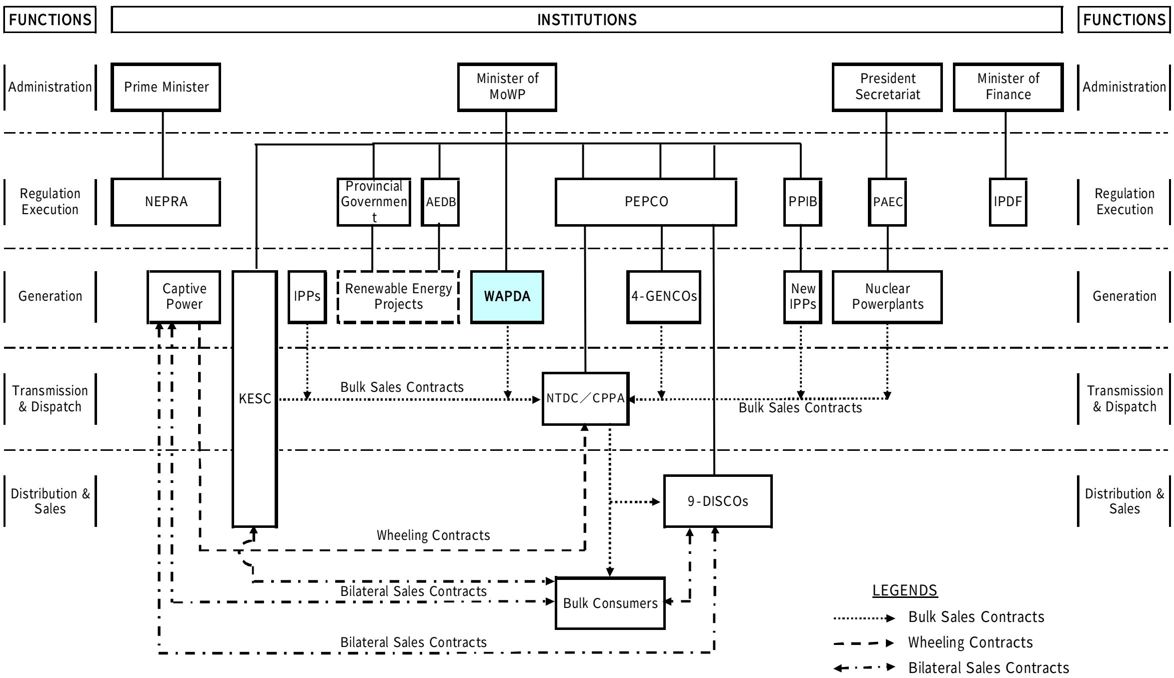
2.4 Power Sector Environment

2.4.1 Current Structure of Power Sector

Formerly, the power sector in Pakistan was primarily managed by WAPDA, which was established in 1958. WAPDA, which has been split into two companies in 1998, provided services throughout the country except for Karachi and its adjoining areas. These areas were served by the Karachi Electric Supply Company (KESC), which was established in 1913. In addition, the Pakistan Atomic Energy Commission (PAEC) established in 1956, has been responsible for all aspects of nuclear power generation working under the President Secretariat.

In 1998, the Government of Pakistan (GOP) established the National Electricity Regulatory Authority (NEPRA) to regulate all aspects of the power sector, including tariff-determination. Later, the GOP divided WAPDA into a new WAPDA and the Pakistan Electric Power Company (PEPCO). PEPCO takes care of and provided technical support to its 14 corporate entities, including four thermal power generation companies (GENCOs), nine distribution companies (DISCOs) and the National Transmission and Power Dispatch Company (NTDC).

The schematic diagram of the power sector in the country is shown in Figure 2-8.

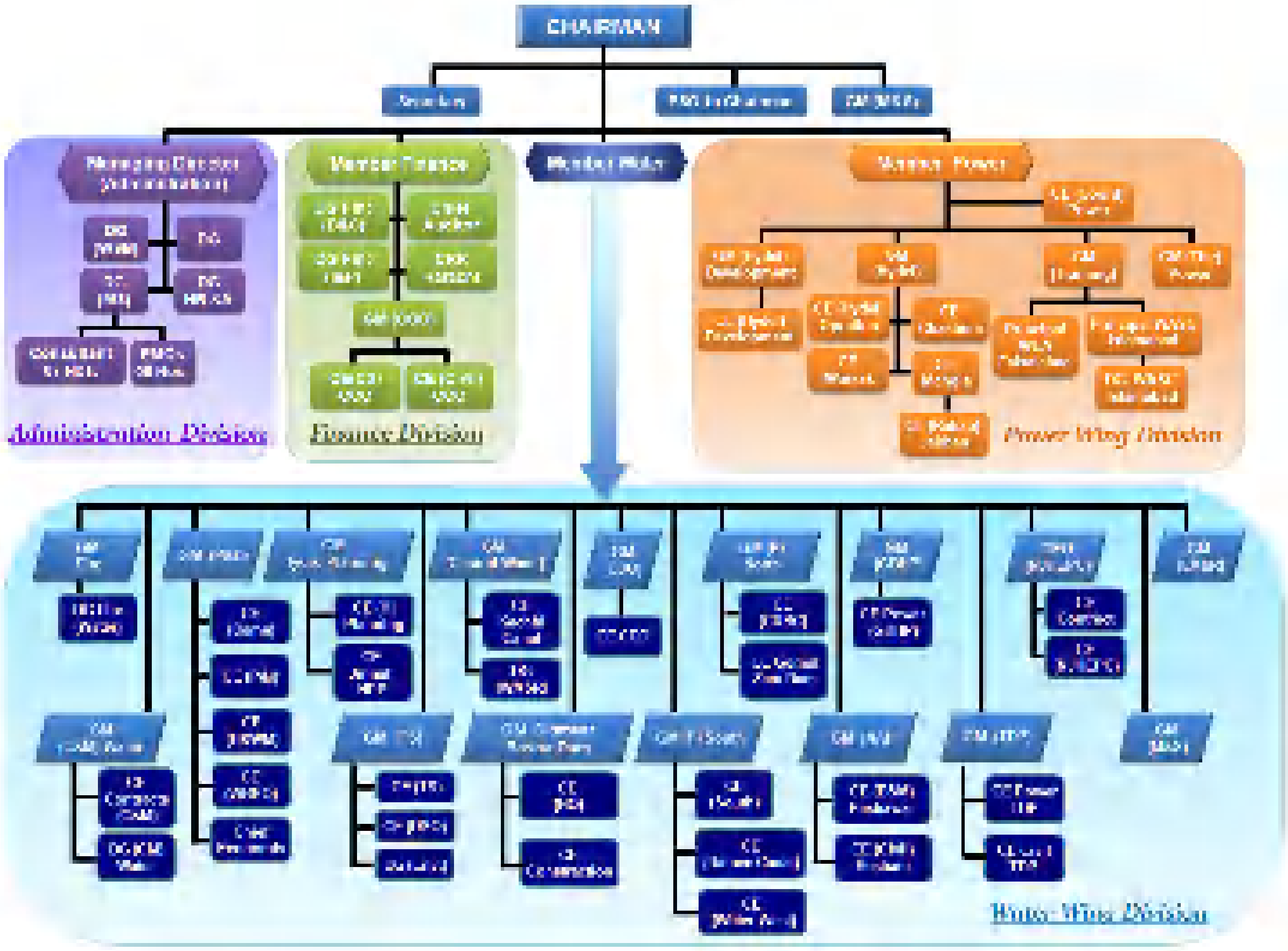


Source: Modified by the Survey Team based on WAPDA's information

Figure 2-8 Schematic Diagram of Power Sector in Pakistan

2.4.2 Organization of WAPDA

The organizational structure of WAPDA is shown in Figure 2-5 below.



Source: Prepared by the Survey Team

Figure 2-5 Organizational Structure of WAPDA

The manpower of each division of WAPDA, as of June 2012, is shown in Table 2-6.

Table 2-6 Manpower of WAPDA

No.	Position	Division				Total
		Administration	Finance	Water Wing	Power Wing	
1	Managerial Staff (BPS 18 to 21)	256	48	132	42	478
2	Sr. Engineers/Sr. Scientific Officer (BPS-18)	-	-	339	61	400
3	Technical Staff	-	-	1,037	1,793	2,830

4	Non-Technical Staff (BPS 1 to 17)	2,963	891	8.308	2,324	14,486
Total		3,219	939	9,816	4,220	18,194

Source: Prepared by the Survey Team

2.4.3 Financial Condition of WAPDA

(1) Trend of Revenue and Profit

The revenue from selling electricity has been gradually increasing despite the decline of generation in 2008 and 2009.

This is mainly due to the increase of bulk supply tariff, which is applied to the NTDC the single buyer of electricity from hydropower stations of WAPDA. The increase of the tariff for 2011-2012, consisting of the fixed charge and the variable charge, has been approved by the NEPRA in November 2011. The fixed charge and variable charge of the tariff (2011-2012) is higher than that of 2009-2010.

The change in the structure of bulk supply tariff has significantly influenced the share of the revenue. Table 2-10 shows the revenue of variable charge which has declined by 26.2% in 2010 to 2011 while that of fixed charge has increased by 32.1%. The fixed charge is calculated based on the capacity of generation while the variable charge is based on the actual amount of sales of electricity, the revenue turned out to be more stable with less influence from the fluctuations of generation.

As the revenue increased and the operating expense decreased between 2010 and 2011, the operating profit has increased by 24.6% from PRs 15,910 million in 2010 to PRs 19,830 million in 2011. The net profit has also increased by 58.7% from PRs 6835 million in 2010 to PRs 10,949 million in 2010.

(2) Issues on the Financial Condition of WAPDA

WAPDA has achieved a good result of revenue and profit. However, there are several issues to be addressed and solved for better financial condition.

Circular Debt Problem

The power sector has been facing circular debt problem. NEPRA approved the tariff petition of the generation and distribution companies, which covered the full cost of generation and distribution. However, GOP notified that the tariff charged to customers will be lower than the full cost recovery level determined by NEPRA.

The GOP has instead promised to pay subsidies to the distribution companies in order to fill the gap in the cost recovery. However, the government has failed to make timely payment of subsidies, which resulted to revenue shortage of the distribution companies and delay in payment for the purchase of electricity from power stations. Power generation companies have been suffering from the increase of receivables and have been forced to stop or delay payments to their fuel suppliers in order to balance their cash flows. However, this has further caused delay in the purchase of fuel by power generating companies.

In the case of WAPDA, the partial failure of payment by the NTDC, which purchases the electricity from hydropower stations of WAPDA based on bulk supply tariff, has worsened the cash flow condition of WAPDA.

Bulk Supply Tariff

The full cost recovery is a pre-condition for a healthy financial condition of WAPDA. As mentioned earlier, WAPDA has obtained the approval for the increase of bulk supply tariff from the NEPRA. However, WAPDA has sent the petition with the proposal of higher tariff than the approved.

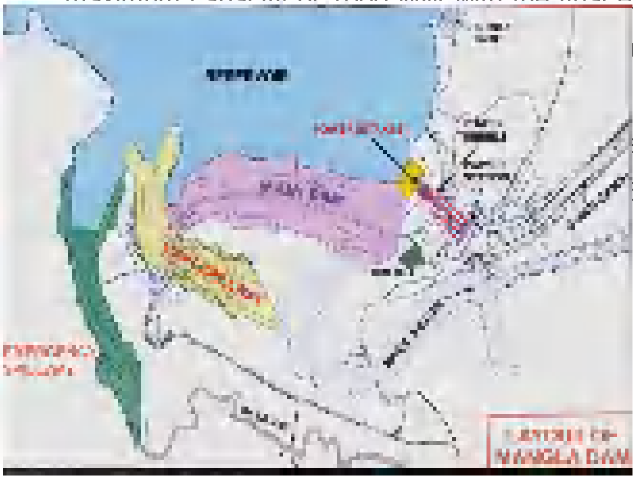
WAPDA has made this proposal because of various factors that influence its financial condition. Among others, the expected increase of O&M cost is a major factor. According to the document submitted to the NEPRA, WAPDA forecasted a significant increase of O&M cost.

The proposed bulk supply tariff based on the expected increase of O&M cost has not been fully approved by the NEPRA. WAPDA plans to submit another petition to the NEPRA this year after the audit of the Financial Statements for 2011 has been completed.

2.5 Mangla Hydro Power Station

2.5.1 General

The Mangla Dam Project completed in 1967 is located on the Jhelum River about 120 km from the Capital Islamabad as illustrated in Figures 2-11 and 2-12. The project attained its maximum capacity of 1000 MW with the final extension of Units 9 and 10 (2 x 100 MW) in



Source: Mangla Power Station Presentation File
"Briefing for JICA on February 28, 2012.pptx"

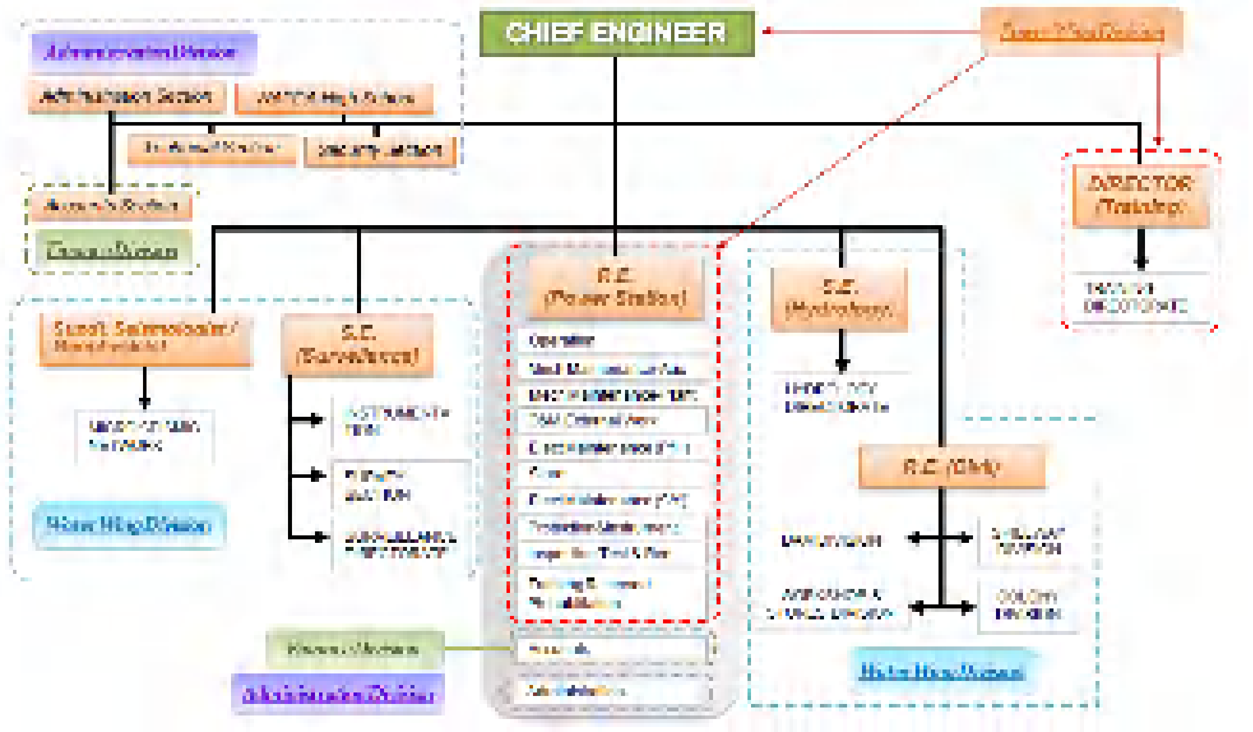
Figure 2-6 Overall Arrangement of Mangla Power Station

Source: Mangla Power Station Presentation File
"Briefing for JICA on February 28, 2012.pptx"

Photo 2-2 Overview of Mangla Power Station

2.5.2 Organization of Mangla Power Station

Mangla Power Station is headed by the chief engineer. The present organization of Mangla Power Station is shown in Figure 2-7.



Source: Prepared by the Survey Team

Figure 2-7 Organizational Structure of Mangla Power Station

The manpower for each section of the Mangla Power Station, as of June 2012, is shown in Table 2-7.

Table 2-17 Manpower of Mangla Power Station

No.	Position	Division				Total
		Administration	Finance	Water Wing	Power Wing	
1	Managerial Staff (BPS 18-21)	-	-	4	2	6
2	Operation Staff (BPS-18)	8	-	14	10	32
3	Technical Staff	-	-	289	344	633
4	Non-technical Staff (BPS 1-17)	-	34	341	90	465
Total		8	34	648	446	1,136

Source: Prepared by the Survey Team

2.5.3 Mangla Dam Raising Project

The Mangla reservoir had an initial capacity of 5.88 minor allele frequencies (MAF), which was reduced to 4.674 MAF in 2005 and will further reduce with the passage of time due to sediment deposition. Keeping in view the capacity loss due to sedimentation and provision for raising it to the original construction design, the raising of Mangla Dam was considered to cope with the ever increasing shortage of irrigation water and mitigate the effects of capacity loss of country's two major storage reservoirs in Mangla and Tarbela. The raising of Mangla Dam by 30 ft has almost been completed to regain the reservoir capacity loss due to sediment deposition and to make provision for future sedimentation.

The contract for the Construction of Main Works (Contract MDR-10) of the Mangla Dam Raising Project was awarded to a joint venture of one Chinese and five Pakistani contractors (CWEJV) on June 14, 2004 for an amount of PRs 13.793 billion. The joint venture is composed of the China International Water and Electric Corporation (CWE) as the lead company, and local contractors including DESCON Engineering, Sardar M. Ashraf D. Baluch, Interconstruct and Sachal Engineering Works. The construction schedule was completed in 39 months in September 2007. Construction of major components for main works i.e., main dam and power intake embankment, Sukian Dyke, Jari Dam and rim works, main and emergency spillways and Mirpur Bypass Road were substantially completed on December 26, 2009 except for some minor varied works.

Table 2-8 Salient Features of Raising of Mangla Dam

Item	Original Design	After Raising	Comparison
Reservoir			
Max. Water Level	366.5 m(1,202 ft)	378.7 m(1,242 ft)	+12.2 m
Min. Water Level	317.1 m(1,040 ft)	317. 1m(1,040 ft)	+0.0 m
Reservoir Capacity	5,553 Mm^3(4.5 MAF)	9,132 Mm^3(7.4 MAF)	+3,579 Mm^3
Dam Body			
Crest Height	138.5 m(454 ft)	147.6 m(484 ft)	+9.1 m
Crest Length	3,350 m(10,300 ft)	3,400 m(11,150 ft)	+50 m
Intake level	376.2 m(1,234ft)	386.0 m(1,266 ft)	+9.8 m
Additional Capacity	-	3,550 Mm^3(2.88 MAF)	-
Annual Generation	-	644 GWh	-

Source：WAPDA Hydrological Section of Mangla Dam

The scope of resettlement works for the Mangla Dam Raising Project is listed below:

- Land acquisition: 16,384 acres
- Number of population: 50,000
- Number of houses and other buildings: 13,404

The actual progress of the resettlement works, as of end of July 2012, is shown in Table 2-9. All construction works for houses, public utility buildings, water treatment system and roads etc., in the new town has been already completed.

Table 2-9 Overall Progress of Resettlement Works

Name of New Town	Overall Progress	Remaining Number of Plots to be Handed Over
MIRPUR NEW CITY	86.3%	169
ISLAMGARH	96.0%	132
CHAKSAWARI	85.6%	362
DUDIAL	100.0%	-
SIAKH	100.0%	-

Source: Mangla Raising Project Office

2.5.4 Hydel Training Center Mangla

The Hydel Training Center Mangla plays a pivotal role in capacity building of the officers and officials of Hydel organizations in WAPDA. It is the sole institution functioning at present to impart training to all the technical/non-technical employees of Water and Power Wings in WAPDA.

According to the annual schedule of training for the year 2012 at Hydel Training Centre Mangla, it is expected that 200 staffs will be trained in year 2012.

CHAPTER 3 REVIEW ON FEASIBILITY STUDY REPORT

3.1 Outline of F/S

3.1.1 Contents of the F/S Report

The F/S report consists of the following eight volumes.

Volume 1 Executive Summary
Volume 2 General
Volume 3 Condition Assessment Generation and Unit Electrical
Volume 4 Condition Assessment Turbine and Unit Electrical
Volume 5 Condition Assessment Balance of Plant
Volume 6 Development and Evaluation of Up-gradation and Rehabilitation Alternative
Volume 7 Environmental Studies
Volume 8 Appendices

3.1.2 Summary of the F/S Report

In the F/S report based on the assessment of the plant equipment, four alternatives namely Alternatives 0, 1A, 1B, and 2, were presented.

The summary of each alternative as described above is shown in Table 3-1.

Table 3-1 Expected Increase in Energy Output by Up-gradation/Refurbishment

Alternative	Unit Rating	Description	Remarks
0	No Up-gradation from the existing 1,150 MW in total (only rehabilitation) Units 1-10: 115 MW	<u>Turbine</u> - Replacement of turbine runner <u>Generator</u> - Replacement of stator winding - Replacement of stator core (Units 1-6) - New static digital excitation system	–
1A	Up-gradation to 1,310 MW in total Units 1-6: 135 MW Units 9-10: 135 MW Units 7-8: 115 MW (no change)	<u>Turbine</u> - Replacement of turbine runner (same as Alternative 0) <u>Generator with higher capacity</u> - Replacement of core and winding for generator (Units 1-6, 9-10) - New static digital excitation system <u>Others</u> - New power transformer and IPB	–

1B	Up-gradation to 1,380 MW in total Units 1-6: 135 MW Units 7-8: 150 MW Units 9-10:135 MW	<u>Turbine</u> - Replacement of turbine runner (same as Alternative 0) <u>Generator with higher capacity</u> - Units 1-6, 9-10: same as Alternative 1A - Units 7-8: complete replacement of generators with 150 MW <u>Others</u> - New power transformer and IPB	–
2	Up-gradation to 1,500 MW in total Units 1-10: 150 MW	<u>Turbine</u> - Replacement of turbine runner (same as Alternative 0) <u>Generator with higher capacity</u> - Units 1-10: complete replacement of generators with 150 MW <u>Others</u> - Modification of intake structure - New power transformer and IPB	Demolition works of existing concrete foundation of generators required for all units except for Units 7 & 8.

Source: Feasibility Study for Up-gradation and Refurbishment of Generating Units of Mangla Power Station, December 2011

Each generating unit from Unit 1 to Unit 10 were ranked utilizing the ranking methodology. It assessed both the condition and the consequence.

The assessment concluded the urgent rehabilitation of generating equipment units 5, 6, 2, 1, 3 and 4 in order.

The construction costs were estimated for each alternative. The net present value (NPV), economic internal rate of return (EIRR), financial internal rate of return (FIRR) and benefit -cost ratio (BCR) were calculated with the utilization of inflation and escalation rates specified for the different inputs.

Table 3-2 Economic Analysis of Up-gradation Alternatives (2013 to 2047)

Alternative	Construction Cost		NPV		EIRR	FIRR	BCR
	million USD	billion PRs	million USD	billion PRs			
Alternative 0 1150 MW	350.8	29.82	181.0	15.38	20.9%	Not done	2.54
Alternative 1A 1310 MW	369.4	31.4	234.9	19.97	24.0%	22.6%	2.89
Alternative 1B 1380 MW	446.2	37.93	222.4	18.91	22.6%	Not done	2.52
Alternative 2 1500 MW	684.3	58.17	158.7	13.49	17.8%	Not done	1.69

Source: Feasibility Study for Up-gradation and Refurbishment of Generating Units of Mangla Power Station, December 2011

The F/S report concluded that Alternative 1A to be the most economically alternative, though the detailed information such as assumptions (discount rate) and methodology (calculation of economic benefit) were not described. It was also difficult to judge the accuracy of the figures shown in the report.

The F/S report also conducted the financial and economic analyses in case of including the benefit from CDM CER credits. The F/S also concluded that the additional benefit is marginal and there is not much difference in the result of calculation.

Table 3-3 Economic Analysis with CDM Allotment (2013 to 2047)

Alternative	NPV with CDM		EIRR w/ CDM	BCR w/ CDM
	million USD	billion PRs		
Alternative 0 1150 MW	N/A	N/A	N/A	N/A
Alternative 1A 1310 MW	246.5	20.95	24.5%	2.98
Alternative 1B 1380 MW	234.3	19.92	23.0%	2.60
Alternative 2 1500 MW	171.1	14.54	18.2%	1.74

Source: Feasibility Study for Up-gradation and Refurbishment of Generating Units of Mangla Power Station, December 2011

3.1.3 Conclusion and Recommendation of the F/S

The F/S report concluded that Alternative 1A (1310 MW total) is recommended since it satisfies all objectives from the scope of works. Alternative 1A also has the highest NPV, BCR, EIRR, and FIRR.

3.2 Recommendation in the F/S and View of the Survey Team

3.2.1 Hydraulic Consideration and Limitations

The hydraulic limitations in the F/S report are the reservoir water level, tailrace water level ,and water passage for consideration of turbine ratings.

When the dam height was increased by 30 feet, the reservoir water level increased by 40 feet, which is from 1202 feet to 1242 feet.

The water passages include the intake screen (trashracs), intake gate, concrete lined tunnel, steel lined tunnel, inlet valve, and tailrace channel (Bong Cannel). The water passage limitation is the base data for deciding the maximum output capacity of the turbine together with the head loss. Maximum water passage limitation is 49,000 cfs, (4,900 cfs/unit) which is the tailrace channel water passage limitation.

3.2.2 Condition Assessment of Turbine and Unit Mechanical

Most of the recommendations on turbine and unit mechanical described in the F/S report are almost acceptable.

3.2.3 Condition Assessment of Generator and Unit Equipment

Most of the recommendations on generator and unit mechanical described in the F/S report are almost acceptable.

However, there were a few site measurement data and analyses by the measuring data. Therefore, the Survey Team has added some analysis by data measured during the site visit. The result of analysis is mentioned in Chapters 4 and 5.

3.2.4 Condition Assessment of Balance of Plant (BOP)

(1) Switchyard

Almost all devices are outdated. The F/S recommended replacing them with modern state-of-the-art substation automation system (SAS). Bus bar protection relays are scheduled to be replaced by digital relays. Battery systems for switchyard are all new within the last 10 years. It is assessed that the battery systems are not required to be replaced immediately.

(2) Station Service

The F/S report described the issues on the station service system as shown below:

The plant operation and maintenance personnel have reported that they faced a number of problems during the restoration process after a blackout scenario when they have to perform multiple manual operations to restore the normal configuration. There are many interlocking devices between the various breakers making the system very complex.

The F/S report recommended replacing the system entirely with a new system. The said report presented several alternative designs for replacement. The final recommendation was chosen to be Option 5 in Table 3-4.

Table 3-4 Alternative Plans for Station Service Refurbishment in the F/S

Alternatives	Outline	Feature
Option-1 (Figure 3-1)	Refurbish but retain existing configuration	The 132 kV system failed to bring power station down.
Option-2 (Figure 3-2)	Refurbish and shift one SOTH to 220 kV side of the switchyard while retaining the existing configuration	The above trouble will be mitigated by using the 220 kV system supply.
Option-3 (Figure 3-3)	Refurbish and revise unit auxiliary supply configuration	Power supply redundancy will be further increased from Option-2. Switches changeover operation and interlock becomes more complicated.
Option-4 (Figure 3-4)	Refurbish and utilize unit block configuration	Automatic unit supply change over circuit is required at unit start/stop time. Switches changeover operation and interlock becomes more complicated. When the 220 kV and 132 kV fail, the same with Option-2.
Option-5 (Figure 3-5)	Refurbish and apply generator circuit breaker configuration	Two generator circuit breakers are attached to Units 2 and 7. Switches changeover operation and interlock becomes more complicated.

Source: Prepared by the Survey Team

In the F/S report, there is no description why Option 5 is recommended preferentially.

The Survey Team assumes the reason of recommendation of Option 5 in the F/S report as below:

1) Option-5 makes redundant power supply system from the two different generation units, which are connected different high voltage bus as 220kV and 132kV. It is more reliable compare to the actual system.
2) Station service power supply will not be affected substation system troubles since the power is directed from the generation bus.

3.2.5 Condition Assessment of Civil Works

(1) Water Balance of Mangla Dam

The F/S report mentioned in the study under civil works includes the hydrological methodology and analysis procedure (RESOP-1 software by NESPAK), the dam sedimentation analysis (HEC-6 software by the United State Army Corps of Engineers) and the countermeasures against concrete degradation of generator and turbine foundations. The hydrological analysis forecast on inflow discharge until year 2097/98 for 88 years were based on the data from year

1922/23 to 2009/10 of the Mangla dam basin using by the RESOP-1 program. The result of the analysis is shown in Table 3-5 below.

Table 3-5 Water Balance in Mangla Dam Basin

Inflow and Outflow	MAF	mm^3
Average Annual Inflow	22.75	28,062
Average Annual Outflow for Irrigation	20.91	25,792
Average Annual Outflow in Kharif (April to September)	10.24	12,631
Average Annual Outflow in Rabi (October to March)	10.67	13,161
Average Annual Spill	2.00	2,467

Source: Feasibility Study for Up-gradation and Refurbishment of Generating Units of Mangla Power Station, December 2011

The penstock discharge from one intake gate was estimated at 9,000 ft^3/s (254.9 m^3/s). In the case of generating power using 10 generators with five penstocks, the planned discharge was calculated at 45,000 ft^3/s (1,274 m^3/s). After generating power at the Mangla Power House, the water flows to the New Bong Power Station (independent power project: IPP).

(2) Concrete Repair at Power House

Based on the results of the evaluation of the F/S report and the description of the site investigation under this study, concrete repair works at generators and turbines in the power houses are under consideration. Some cracks in the concrete surrounding the turbines have been observed, specifically at Units 5 and 6 which have big cracks with approximately 5 mm width. According to the F/S report, the use of epoxy injection and replacement of concrete with approximately 5.4 m^3 were recommended as solution. However,, this study shall recommend the use of epoxy injection and carbon fiber sheet. The reason for the occurrence of the serious cracks is not mentioned in the F/S report. In addition, the surrounding concrete of Unit 8 turbine has some leakage which should be repaired. The surrounding concrete of each intake structures (5 intakes in total) also have some minor cracks, which shall also be injected with epoxy, as recommended by the F/S report. However, more cracks from the concrete surrounding the turbines and generators of Units 1, 2, 4, 7, 9, and 10 were observed but not structurally serious. Concrete strength was examined using Schmidt Hammer and found no deterioration on the concretes. The locations recommended for repair/reinforcement under the study are shown in Table 3-6.

Table 3-6 Location for Concrete Repair and Strength of Existing Concrete

<table>
<tr><th></th><th>No.1</th><th>No.2</th><th>No.3</th><th>No.4</th><th>No.5</th><th>No.6</th><th>No.7</th><th>No.8</th><th>No.9</th><th>No.10</th></tr>
<tr><td>Turbine</td><td></td><td></td><td></td><td></td><td>○</td><td>○</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Leakage</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>○</td><td></td><td></td></tr>
<tr><td>Intake</td><td colspan="2">○</td><td colspan="2">○</td><td colspan="2">○</td><td colspan="2">○</td><td colspan="2">○</td></tr>
<tr><td>Concrete Strength (MPa)</td><td>48.2</td><td>50.3</td><td>44.0</td><td>48.5</td><td>51.6</td><td>52.4</td><td>50.2</td><td>51.6</td><td>48.3</td><td>50.2</td></tr>
</table>

Note: Locations for repair are described as ○ Standard strength for concrete is F=30 MPa
Source：Prepared by the Study Team

(3) Evaluation of Sedimentation

The sedimentation volume in the future may be estimated as follows and the comparison between the F/S report and actual survey data was conducted and summarized in Table 3-7.

1) Using sedimentation volume based on the previous surveyed data (1967-2010) and applying the same ratio to year 2011-2093.
2) Using sedimentation volume based on the sedimentation analysis for the F/S

Accordingly, the sedimentation will be reduced in the next 83 years by approximately 8%. It was explained that the mountainous slopes and river courses will gradually stabilize in the future. The sedimentation analysis in the F/S report may be correct and it would be the proper approach to calculate the volume of future sedimentation.

Table 3-7 Evaluation of the F/S Report on Sedimentation

Year		1967-2010	2011-2050	2051-2093	Total
Duration		44 years	40 years	43 years	127 years
Catchment Area		33,343 km^2			-
Sedimentation Volume	Actual Survey	1,589 mm^3	1,445 mm^3	1,554 mm^3	4,588 mm^3
		(0.5%)	(0.5%)	(0.5%)	
	WAPDA F/S Report	1,589 mm^3	1,461 mm^3	1,178 mm^3	4,228 mm^3
		(0.5%)	(0.4%)	(0.3%)	

Note: Figure inside the parenthesis describes the reducing rate of reservoir storage capacity
Source: Prepared by the Survey Team

3.3 Points to be stated in the F/S Report and to be considered in the Detailed Design

3.3.1 Points to be Stated in the F/S Report

The following items have not been studied in the F/S report.

(1) Estimation of winding life

(2) Measuring data

(3) Maximum gross head and effective head after dam raising.

3.3.2 Main Points to be Considered in the Detailed Design

The following items shall be considered at the Detailed Design Stage.

(1) Lower bearing bracket

(2) Rotating parts weight and water thrust

(3) Operation limit study and setting change

(4) Station service circuit

CHAPTER 4 FINDINGS OF THE PLANT SURVEY

4.1 Basic Features of the Plant

4.1.1 Dam Water Level

The basic features of the water level of Mangla Dam for generation are shown in the following Table 4-1:

Table 4-1 Basic Features of the Plant

Contents	Before Dam Raising	After Dam Raising
Max. Reservoir Water Level	EL 1,102 ft = 336.1 m	EL 1,142 ft = 348.3m

Source: Prepared by the Survey Team

4.1.2 Turbine

The main ratings of turbine are as follows:

i. Units 1 through 4

Manufacturer	Mitsubishi Heavy Industry, Japan
Type	Francis
Rated Output	138,000 BHP at 295 ft head (103 MW at 89.9 m head)
Maximum Output	198,000 BHP at 380 ft head (147.7 MW at 115.8 m head)
Rated Discharge	4,550 cfs (129 m^3/s)
Rated Speed	166.7 rpm
Rough zone	0-80 MW, with a less rough spot around 30 MW
Commissioning Year	1967 for Units 1 and 2, 1968 for Unit 3, 1969 for Unit 4

ii. Units 5 and 6

Manufacturer	CKD Blansko, Czechoslovakia
Type	Francis
Rated Output	138,000 BHP at 295 ft head (103 MW at 89.9 m head)
Maximum Output	198,000 BHP at 380 ft head (147.7 MW at 115.8 m head)
Rated Discharge	4,515 cfs (128 m^3/s)
Rated Speed	166.7 rpm
Rough zone	0-80 MW, with a less rough spot around 30 MW
Commissioning Year	1973 for Unit 5, 1974 for Unit 6

iii. Units 7 and 8

Manufacturer	ACEC, Belgium
Type	Francis
Rated Output	103 MW
Maximum Output	148 MW
Rated Discharge	4,306 cfs (122 m^3/s)
Rated Speed	166.7 rpm
Rough zone	0-80 MW, with a less rough spot around 50 MW
Commissioning Year	1981

iv. Units 9 and 10

Manufacturer	CKD Blansko, Czechoslovakia
Type	Francis
Rated Output	103 MW at 90 m/295 ft head
Maximum Output	148 MW at 115 m/380 ft head
Rated Discharge	4,515 cfs (12.9 m^3/s)
Rated Speed	166.7 rpm
Rough zone	0-80 MW, with a less rough spot around 50 MW
Commissioning Year	1993 for Unit 9, 1994 for Unit 10

4.1.3 Generator

The main ratings of generator and electrical equipment are as follows:

i. Units 1 through 4

Manufacturer	Hitachi, Japan
Rated Output	125,000 kVA
Rated Power Factor	0.8
Rated Voltage	13,200 V
Rated Frequency	50 Hz
Rated Speed	166.7 min^{-1}
Insulation Class	B
Overload	115%
Year of Manufacture	1965 for Units 1, 2, and 3, 1967 for Unit 4

ii. Units 5 and 6

Manufacturer	SKODA, Czechoslovakia
Rated Output	125,000 kVA
Rated Power Factor	0.8

Rated Voltage	13,200 V
Rated Frequency	50 Hz
Rated Speed	166.7 min^{-1}
Insulation Class	F
Overload	115%
Year of Manufacture	1971

iii. Units 7 and 8

Manufacturer	Hitachi, Japan
Rated Output	125,000 kVA
Rated Power Factor	0.8
Rated Voltage	13,200 V
Rated Frequency	50 Hz
Rated Speed	166.7 min^{-1}
Insulation Class	B
Overload	115%
Year of Manufacture	1979

iv. Units 9 and 10

Manufacturer	SKODA, Czechoslovakia
Rated Output	125,000 kVA
Rated Power Factor	0.8
Rated Voltage	13,200 V
Rated Frequency	50 Hz
Rated Speed	166.7 min^{-1}
Insulation Class	F
Overload	115%
Year of Manufacture	1991

4.2 Operating History of the Plant

(1) Commissioning Dates and Accumulated Operating Hours

Commissioning dates and total operating hours since commissioning for each unit shown in the following Table 4-2:

Table 4-2 Total Operating Hours (up to 31 Dec. 2011)

Unit Number	Total Operating Hours	Commissioning Date	Unit Number	Total Operating Hours	Commissioning Date
Unit 1	361,373 hrs	03/07/1967	Unit 6	263,583 hrs	11/03/1974
Unit 2	360,017 hrs	14/07/1967	Unit 7	203,276 hrs	19/06/1981
Unit 3	301,809 hrs	07/03/1968	Unit 8	190,092 hrs	22/08/1981
Unit 4	297,087 hrs	17/06/1969	Unit 9	100,223 hrs	24/09/1993
Unit 5	268,864 hrs	29/12/1973	Unit 10	90,364 hrs	06/07/1994

Source: WAPDA (Mangla Hydro Power Station)

(2) Number of Start/Stop

List of number of start/stop of each unit is collected and shown in the following Table 4-3:

Table 4-3 Number of Start/Stop

Unit Number	**Number of Start/Stop**	**Unit Number**	**Number of Start/Stop**
Unit 1	1,265	Unit 6	2,142
Unit 2	1,716	Unit 7	3,501
Unit 3	5,219	Unit 8	4,054
Unit 4	4,777	Unit 9	3,301
Unit 5	2,040	Unit 10	3,260

Source: WAPDA (Mangla Hydro Power Station)

From the above table, there are some points which were clarified by WAPDA as described below.

A large difference between the total numbers of start/stop of Units 1 and 2 and those of Units 3 and 4 is found from the above table. This reason is to avoid overloading of 138 MVA, 132/220 kV interconnector transformers and to enhance system stability, as Units 1 and 2 are connected to 132 kV bay in the switchgear while Units 3 and 4 are connected to 220 kV bay. Therefore, the numbers of start/stop of Units 1 and 2 are less as compared to Units 3 and 4.

4.3 Maintenance Management

4.3.1 Staffs for the Maintenance Work

The maintenance work of all mechanical and electrical equipment of Mangla Power Station is carried out by Mechanical Maintenance Auxiliary Section, Mechanical Maintenance Plant Section, Operation and Maintenance External Work Section, Electrical Maintenance (Power House) Section, and Electrical Maintenance (Switch Yard) Section under the organization of Mangla Power Station as described in Sub-clause 2.5.2.

4.3.2 Maintenance Conditions

All equipment are properly maintained by power station maintenance staffs and the prescribed check sheets/formats are duly filled by them on daily, monthly, and biennial bases.

This is the reason that all the equipment are in good condition and operating safely though more than 40 years have passed especially for Units 1 to 4.

4.3.3 Subcontract for Maintenance

The maintenance work is done by WAPDA without any maintenance contract with any original supplier or any maintenance company. Main equipment such as turbine/generator are maintained properly by the staffs who were trained by the original manufacturers.

4.3.4 Spare Parts Management

Most of the spare parts are stored in the warehouse properly. According to the information of the store engineer, sufficient spare parts are stocked except for Units 5 and 6. Stator windings were stored with dust but they are in useful condition, and carbon brushes are available from the market in Pakistan.

Furthermore, the most important apparatuses such as lifting beam for tandem operation by two overhead travelling cranes and lifting device to lift up the generator rotor are stored in the erection bay with good maintenance.

4.4 Hydraulic Mechanical

4.4.1 General

Total nominal discharge capacity	: 49,000 cfs (1,386 m^3/s)
Each tunnel discharge capacity	: 9,800 cfs (277 m^3/s)

4.4.2 Turbine Inlet Valves

(1) Units 1 through 4

Type	: Butterfly with solid disc
Manufacturer	: Mitsubishi Heavy Industry, Japan
Size	: 16 ft (4.88 m) diameter
Design Head	: 560 ft (170.8 m)

(2) Units 5 and 6

Type	: Butterfly with solid disc
Manufacturer	: Mitsubishi Heavy Industry, Japan
Size	: 16 ft (4.88 m) diameter
Design Head	: 560 ft (170.8 m)

(3) Units 7 and 8

Type	: Butterfly with bi-plane disc
Manufacturer	: ACEC, Belgium
Size	: 16 ft (4.88 m) diameter
Design Head	: 560 ft (170.8 m)

(4) Units 9 and 10

Type	: Butterfly with flow through disc
Manufacturer	: CKD Blansko, Czechoslovakia
Size	: 16 ft (4.88 m) diameter
Design Head	: 560 ft (170.8 m)

4.5 Turbine and Unit Mechanical Equipment

The vibration and noise level of turbine and unit mechanical equipment are measured on all operating units. The Survey Team confirmed that there is no abnormal vibration and noise level for the existing turbine and unit mechanical equipment.

(1) Noise Level Measurement

Measurement positions for checking the noise level are presented below:

1) About 1 m from the turbine pit entrance
2) Turbine pit inside
3) About 1 m from draft tube manhole

(2) Vibration Level Measurement

Measurement positions for checking the vibration level are presented below:

1) Turbine bearing
2) Surrounding turbine upper cover fixing bolt
3) Top of the guide vane
4) Surrounding centre of draft tube manhole
5) Top of generator upper bracket

4.6 Generator

4.6.1 Current Operating Conditions

(1) Insulation Resistance Measurement Test

In addition to the data collection, the Survey Team measured insulation resistance of stator winding of Unit 6, which has been stopped for normal maintenance work since February 29, 2012. From the above figure, polarization index (PI) value for each phase is as follows:

Phase A: 22.5
Phase B: 24.3
Phase C: 22.5

These figures appeared too high, and when the measuring data is read, the measuring range was changed after 1 minute reading. The 2 min. to 10 min. readings have the same range. Therefore, tentative PI values are just calculated as (10 min. value)/(2 min. value) and these figures are:

Phase A: 4.5
Phase B: 6.1
Phase C: 6.4

These figures are still more than 2.5. Therefore, the coils are not in absorption condition. This is because WAPDA's maintenance is so good. ("More than 2.5" is quoted from the Technical Report No. 752 issued by The Institute of Electrical Engineers of Japan. This report suggested that PI should be more than 1.5 to 2.5)

The above measurement data reveal that all the stator coils are operating in good condition.

(2) Power Factor under Operation

Power factor was calculated by dividing the generated power (MW) by the reactive power (MVar) from the operation record on a typical day having maximum power generated for each month during 2011.

The above data show that all units are operated with power factor of more than 0.9 although the rated power factor is 0.8.

(3) Temperature of Stator Winding and Thrust Bearing

Temperature of stator winding and thrust bearing was confirmed without any problem from the past operation records.

(4) Past Incident Record

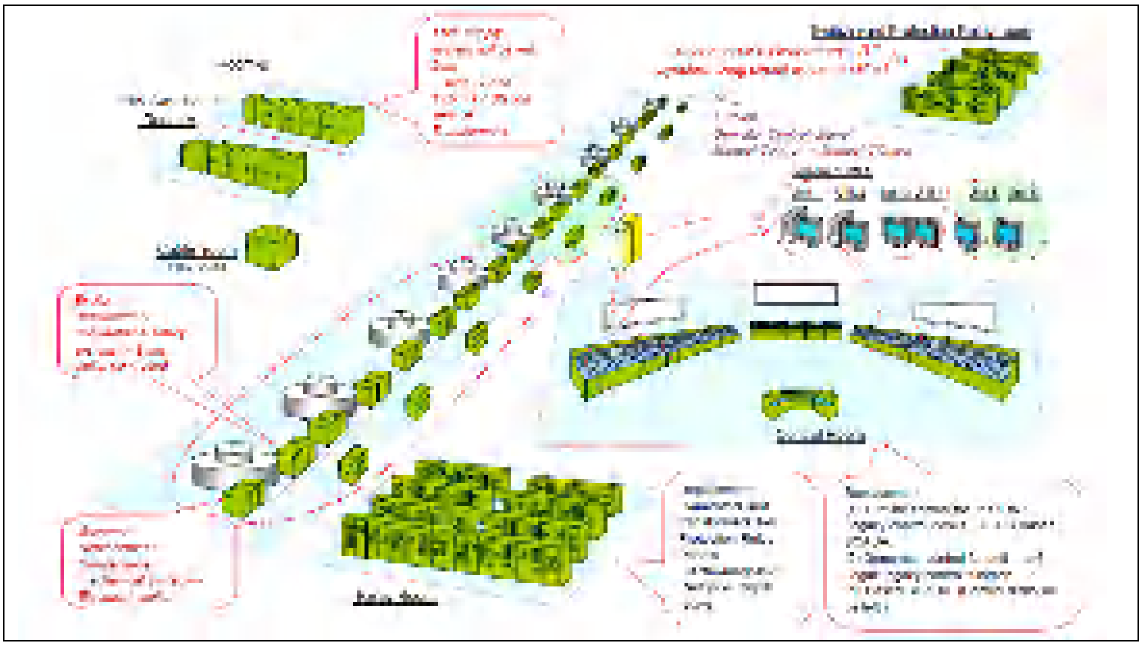
Major faults and/or incidents occurred only in Units 5 and 6. These faults are considered caused by the damage of stator windings.

4.7 Control and Protection

4.7.1 Present Situation of Control and Protection System

The control and protection system have been modified whenever generation units and transmission lines were expanded. At present, 220 kV and 132 kV transmission lines and ten sets of turbine-generator, intake gates, and irrigation valves are supervised and controlled from the control room of the Mangla Power Station.

Figure 4-1 below shows the overview of control and protection facilities for Mangla Power Station.



Source: Prepared by the Survey Team

Figure 4-1 Conceptual Picture of Power Station Control System

The system is well managed and maintained by the staffs of the power station. Though the system performance is maintained as the original condition, the devices and wires in the control and protection circuit were deteriorated. The renewal of such wires and devices is a pressing issue for reliable operation.

4.7.2 Control and Protection for Turbine-Generator

(1) Control

The present control is through manned manual semi-automatic start control. The generator and turbine status are continually monitored at the generator room through the governor/turbine.

Control cabinets and AVR/generator control the cabinets. The control room also monitors such status as needed through the control desks.

The unit is controlled, step by step, from the control room with manual operating or regulating switches on the control desk. The operation proceeds through the following steps by the operator manually:

Inlet valve open → Turbine start → Excitation → Synchronizing

Auxiliary equipment such as cooling water pumps and oil pressure pumps are controlled locally with local control panels. The system consists of conventional magnetic relays, switches, and indicators.

(2) Protection

There are three trip modes, i.e: 86-1, 86-2, and 86-3. The irrigation valve control is required at the trip situation. The protection relays are almost BBC's and Hitachi's old electro-mechanical types. The relays are well maintained; however, the potential of malfunction or non-operation due to aging cannot be measured.

(3) Irrigation Valve Control

The irrigation valves require combinational governing operation with turbine. The new design must involve such operation manner.

4.7.3 Control and Protection for Generation Units

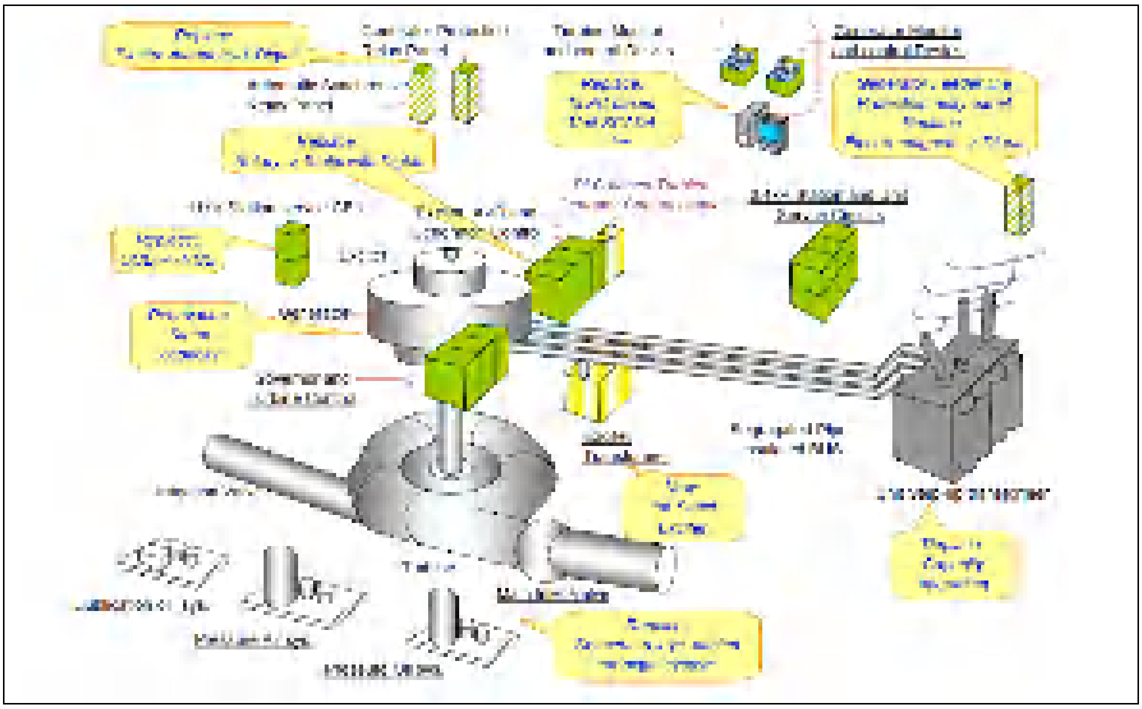
Main equipment and their peripheral equipment are summarized in the following Table 4-4. These are targets for control and protection of generation units.

Table 4-4 Target Equipment of Generation Units Control System

Main Equipment	Peripheral Equipment
Turbine	Turbine, Irrigation Valve, Governor/Turbine Control Panel and Peripheral Equipment of the Turbine.
Generator	Generator, Exciter, AVR/Generator Control Panel, IPB and Peripheral Equipment of the Generator.
Step-up Transformer	Step-up Transformer, Cooling System for the Transformer, Tap Changer and Peripheral Equipment of the Transformer.

Source: Prepared by the Survey Team

The image of control equipment and subjected control facilities are shown in Figure 4-2 below.



Source: Prepared by the Survey Team

Figure 4-2 Conceptual Picture of Generation Unit Control System

4.7.4 Control and Protection for Step-up Transformer

(1) Control

The generation unit does not furnish the generator circuit breaker. The generator feeder is directly connected to the step-up transformer. High voltage feeder of the step-up transformer is connected to one and half circuit breakers.

The step-up transformer furnishes off-load tap changer and transformer cooling system. The transformer status is monitored from the control room.

(2) Protection

The protection relay for transformer consists of conventional electro-magnetic protection relays and mechanical relays such as Buchholz relay. Both the generator heavy fault and transformer heavy fault bring the generator emergency stop into high voltage (220 kV or 132 kV) circuit breaker trips.

4.7.5 Control and Protection for Switchyard

(1) Circuit Configuration

The facilities of power transmission are installed in the switchyard. The system consists of eight transmission lines with one and half circuit breaker configuration (1.5 CB) on 220 kV and 13 transmission lines with one and half circuit breaker configuration (1.5 CB) on 132 kV. The 132 kV and 220 kV systems are linked by the three inter-connection transformers. The two generators are connected to the 132 kV system via two step-up transformers while eight generators are connected to the 220 kV system via eight step-up transformers.

The switchyard facilities are monitored and controlled from the control room in the powerhouse. The protection relays for switchyard facilities are installed in the relay room in the switchyard. The control and protection signals are linked by the long distance (about 2 km) cables between the powerhouse and the switchyard.

(2) Actual Refurbishment Work

The replacement work of old circuit breakers and protection relays is implemented along the NTDC/NPCC's plan. The SCADA of Mangla switchyards has been implemented by NTDC/NPCC. It intends to control the circuit breakers from the dispatch center and control room of Mangla via SCADA system.

(3) Control

The control and protection system mainly consists of conventional wired logic relay schematic sequence circuits. Indicator, auxiliary relays and wires are still used from the original installed condition.

(4) Protection

Actually, generator feeder line protections are installed in the same protection panels of transmission lines, which are connected to same bays of feeder lines.

4.7.6 Control and Protection for Station Service System

(1) Alternative Current (AC) Power Supply

The 132 kV bus supply the power to two sets of station service transformers (132/11 kV-7.5 MVA), and each transformer supplies power to two split buses. In total, 19 transformers (11/0.4 kV) are connected to these buses, and the transformers supply the 400 V AC to the stations' facilities.

(2) Direct Current (DC) Power Supply

Mangla control system uses two levels of DC voltages. One is 230 V DC for control and device drive, and another is 50 V for status indication and alarming.

There are two DC 230 V battery systems. One system is for Units 1 to 6 and another system is for Units 5 to 10. One battery set consists of two banks (170 Ah - 2 sets) of batteries, and two sets of battery chargers.

Battery banks have been renewed during the last ten years. There is no requirement for replacing them.

4.8 Switchyard

4.8.1 Outline of Switchyards

The 132/220 kV switchyard, as shown in Photo 4-19, is located at about 1.2 km southeast from the power station. The switchyard is an outdoor conventional type with one and half circuit breaker configuration.

The 132 kV and 220 kV bus are connected by three 132 kV/220 kV 138 MVA transformers with total capacity of 414 MVA.

Two generators of Units 1 and 2 are connected to the 132 kV bus and the generators of Units 3 to 10, eight units in total, are connected to 220 kV bus through their generator step-up transformers.

Eleven 132 kV and eight 220 kV transmission lines are emanated from the switchyard. Besides, two transmission bays are prepared in 132 kV for future expansion.

4.8.2 Generator Connection to Switching Station Bus

The power flow in the switchyard is always one-way, namely, 220 kV to 132 kV, through the 220 kV/132 kV inter-connecting transformer.

In January 2010, 310 MW power flow was recorded, which exceeded the capacity of two 138 MW transformers (276 MW in total). Then, one 138 MW inter-connecting transformer was additionally installed by the end of 2011 for sufficient capacity.

Monthly maximum power flows of 220 kV to 132 kV in 2010 and 2011 are shown in Figures 4-3 and 4-4, respectively. Maximum power flows vary from 200 MVA to 250 MVA. About 310 MVA was recorded in January 2010.

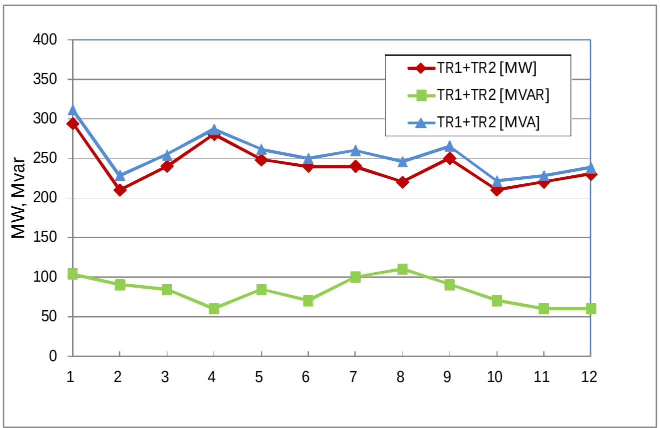


Figure 4-3 Power Flow of 220 kV to 132 kV
in Switching Station in 2010

Source: WAPDA (Mangla Hydro Power Station)

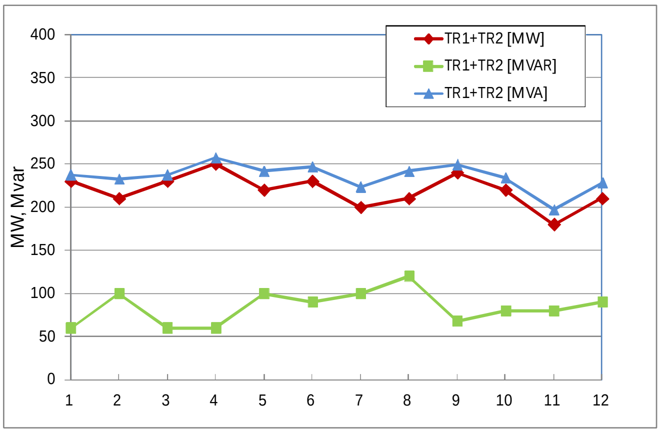


Figure 4-4 Power Flow of 220 kV to 132 kV
in Switching Station in 2011

Source: WAPDA (Mangla Hydro Power Station)

4.8.3 Switchgears

There are 27 and 29 (total 56) circuit breakers for 220 kV and 132 kV side, respectively. The circuit breakers were originally air-blast type. However, they are in the process of being replaced with SF6 type breakers.

As of May 2012, 21 and 24 circuit breakers for 220 kV and 132 kV, respectively, have already been replaced to SF6 type. Then, 6 and 5 circuit breaker for 220 kV and 132 kV, respectively, are scheduled to be replaced in the near future.

4.9 Existing Conditions for Mangla Dam

4.9.1 Meteorology Feature

There are four seasons in Pakistan, i.e.: winter with cold and dry season from December to February, spring with hot and dry season from March to May, summer with hot, rainy and monsoon season from June to September, and autumn as transition period from October to November. Pakistan's climate consists of the desert climate (BW) in the central southern area, steppe climate (BS) in the northern area, and temperate climate in summer rain (Cw) in the northern mountainous area. There are five meteorological stations upstream of Mangla Dam and the monitoring of temperature, humidity, precipitation, evaporation, insolation time, and wind direction/velocity is done by WAPDA. The data is kept by the Surface and Water Division of Hydrology (GM of Planning and Design: Mr. Irshed Ahmad) of WAPDA.

Table 4-5 Location of Meteorological Stations Maintained by WAPDA

Station	River Basin	Latitude	Longitude	Elevation
Domel	Upper Jhelum	34°22′04″	73°28′08″	686 ft (209.1 m)
Pallandri	Lower Jhelum	33°43′10″	73°41′06″	1,402 ft (427.3 m)
Kotli	Poonch	33°29′05″	73°52′52″	610 ft (185.9 m)
Kallar	Kanshi	33°25′00″	73°22′00″	518 ft (157.9 m)
Mangla Dam	Local	33°07′28″	73°38′00″	282 ft (86.0 m)

Source：WAPDA P&D Division

The meteorological station of Mangla Dam recorded 40ºC as the maximum temperature in May and 4ºC as the minimum temperature in December and January.

For the annual precipitation, the Domel and Plandari stations have 1343 mm and 1109 mm, respectively. Precipitation in Kotli, Kallar, and Mangla Dam stations were 975 mm, 793 mm, and 783 mm, respectively, which constituted comparatively less rain.

4.9.2 Basin of Mangla Dam

The river system in the Mangla Dam basin consists of Neelum, Kunhar, Upper Jhelum, Lower Jhelum, Poonch, and Kanshi rivers.

The inflow area from AJK India side was 55.3% of total catchment area and its 73.3% came from the Upper Jhelum River. The inflow area from the Pakistan side was 44.7% and its 32.6% came from Neelum River and 33.5% from Lower Jhelum River.

4.9.3 Water Balance of Reservoir

Mangla Dam's reservoir capacity was estimated at 5,553 million m^3 before raising and the balance between inflow and outflow during the operation from 1968 to 2011 is shown in Figure 4-24. The averages of inflow and outflow were 27,600 million m^3 (22.376 million AF) and 27,545 million m^3 (22.331 million AF), respectively. The outflow used for the power generation was estimated at 23,981 million m^3 (19.442 million AF) on average and it is supplied for irrigation after generation as per intent of Indus River System Authority (IRSA). Also, the water volume released during big floods was 3,729 million m^3 (3.023 million AF) on average through the main spillway.

4.9.4 Sedimentation of Mangla Dam

According to the monitoring reports of Mangla office of WAPDA, there are three major pockets for the sediment volume such as Main Pocket, Jhelum Upper Pocket, and Poonch Pocket. The total sediment from 1967 to 2010 was measured at 1,589.65 million m^3 and the average sedimentation per year was estimated at 36.13 million m^3. The maximum sedimentation was observed in 1978 and 1993 from the hydrographic surveys for sediment. However, the sedimentation volume was decreasing after 2000 due to stability of the riverbed and the catchment area slopes.

CHAPTER 5 STUDY ON REHABILITATION AND ENHANCEMENT

5.1 Turbine

5.1.1 Study on Rehabilitation of Turbine

(1) Units 1 to 4

1) Inlet Valve

The water leakage from the inlet valve when fully closed is so excessive that it is difficult to reduce by simple maintenance works. When any maintenance work inside the turbine is required, the intake gate is closed, which results to the stoppage of the two units. Without closing intake gate, it is very difficult to do any work inside the turbine due to excessive leakage water from fully closed inlet valve. A bi-plane type inlet valve is recommended to minimize water leakage for doing any work inside turbine without closing intake gate but closing inlet valve. By replacing inlet valve to bi-plane type one, head loss would be reduced is effective for high efficiency power generation together with only one unit stopping for one unit turbine inside work.

In consideration of the above, the Survey Team recommended replacing the existing butterfly inlet valve by a bi-plane type, although the F/S report recommended that the existing butterfly inlet valve be repaired only for utilization in the future.

2) Spiral Casing

Overhaul of the spiral casing with partial replacement and repair is recommended. Measuring instruments, including the turbine water flow detector, shall be replaced to match the new design monitoring system. Almost all the measuring signals shall be transferred to new control system. It is difficult to add the signal transfer unit to existing measuring instrument due to out-of-date instrument.

3) Turbine Runner

The turbine runner shall be replaced with a new designed runner.

4) Guide Vane

Guide vanes shall be replaced with the latest design.

New design guide vane is not required feeding lubricant grease.

5) Guide Vane Operating Mechanism

Overhaul of the guide vane operating mechanism is required for replacement of some parts except gate operating ring which shall be reused.

6) Head Cover

The head cover shall be replaced in order to adopt the new design of the turbine shaft and shaft seal.

As recommended below item (8), shaft seal is recommended to replace, in this case, head cover shall also be replaced for mounting the new shaft seal equipment.

7) Turbine Shaft

Inspection and spare preparation of the turbine shaft is requested, however, there is no need for a spare shaft as suggested in the F/S report. Because there is almost no possibility using spare shaft forever.

8) Shaft Seal

The shaft seals shall be replaced with new designs for improving their performance.

9) Discharge Ring and Draft Tube

Inspection of the discharge ring and draft tube liner, and treatment with blasting and re-coating are required.

10) Turbine Guide Bearing

The guide bearing shall be replaced with new one.

11) Governor

The governors shall be replaced with the latest design, which is of digital type and requires a speed signal generator (SSG) with speed detector.

12) Governor Pressure Oil System

The governor pressure oil system shall be replaced with a new design for long life operation of the system.

(2) Units 5 and 6

Units 5 and 6 rehabilitation is the same as Units 1 to 4, except for the following equipment:

1) Guide vane operating mechanism

Overhaul of the guide vane operating mechanism is required for replacement of some parts except gate operating ring which shall be reused.

2) Turbine shaft

The turbine shaft shall be replaced with a new one.

(3) Units 7 to 10

Although overhaul of Units 7 to 10 is also required with the replacement of some equipment, the operation period of these units is not so long as compared to Units 1 to 6. Periodical maintenance shall be required.

An output power limitation control is required after raising the reservoir level in order to prevent damage due to the limitation of the capacity of the generator, including IPB and the main transformer.

5.1.2 Study on Rehabilitation of Auxiliary Equipment for Turbine

(1) Cooling Water System

The cooling water system is currently functional without any major fault, but piping and valve replacement are required for continuous reliable operation for another 40years.

(2) Compressed Air Systems for Generator Brakes

No replacement is required.

(3) Oil-lifting Equipment

No replacement is required.

(4) Overhead Traveling Crane and Lifting Beam for Generator rotor

According to the information of a senior mechanical engineer in Mangla Power Station, the conditions of both cranes are satisfactory. Therefore, no replacement of the parts is required. In addition, the lifting beam for tandem operation of both cranes and the lifting device for the rotor is safely stored in the erection bay.

5.1.3 Study on Enhancement of Turbine

The scope of the works for enhancement of turbine and unit mechanical equipment is same as that for rehabilitation as mentioned in Sub-clause 5.1.1.

The output water limitation shall be considered for limiting the generator output due to the limitation of electrical equipment such as generator, IPB, and main transformer.

5.1.4 Study on Enhancement of Auxiliary Equipment for Turbine

(1) Cooling Water System

The cooling water system is currently functional, but piping and valve replacement is necessary for continuous reliable operation for another 40 years.

(2) Compressed Air Systems for Generator Brakes

If more capacity is necessary from the existing capacity, replacement should be considered.

(3) Oil Lifting Equipment

If the existing capacity is not adequate, then replacement of the lifting equipment should be considered.

5.2 Generator

5.2.1 Study on Rehabilitation of Generator

(1) Study of Generator Stator Coil

From the data of “number of start/stop” and “operating hours”, the remaining life of the stator winding is estimated by N-Y Map method which is presented in the report of the “Institute of Electrical Engineers of Japan”.

i. Unit 1

Operating hours since the commissioning up to the end of 2011: 361,373 hours

Number of start/stop: 1,265

ii. Unit 2

Operating hours since the commissioning up to the end of 2011: 360,017 hours

Number of start/stop: 1,716

iii. Unit 3

Operating hours since the commissioning up to the end of 2011: 301,809 hours

Number of start/stop: 5,219

iv. Unit 4

Operating hours since the commissioning up to the end of 2011: 297,087 hours

Number of start/stop: 4,777

As for units 1 to 4, the residual breaking voltage showed less than 30%, which means that the stator windings of these generators are already beyond its typical life expectancy. Therefore, the stator coils for this unit need to be replaced.

v. Unit 5

Operating hours since the commissioning up to the end of 2011: 268,864 hours

Number of start/stop: 2,040

Stator coils were rewound in 1991 and repaired in 2010.This unit is now operating at reduced load. However, the replaced coils are not from the original manufacturer, thus, the stator coils are recommended to be replaced.

vi. Unit 6

Operating hours since the commissioning up to the end of 2011: 263,583 hours

Number of start/stop: 2,142

As the design of the generator of this unit is the same as Unit 5, the same trouble as Unit 5 is expected. Therefore, stator coils are recommended to be replaced.

vii. Unit 7

Operating hours since the commissioning up to the end of 2011: 203,276 hours

Number of start/stop: 3,501

viii. Unit 8

Operating hours since the commissioning up to the end of 2011: 190,092 hours

Number of start/stop: 4,054

As for units 7 and 8, the stator coil of this unit is also in its last stage of life, but only 30 years have passed since the commissioning and the result of the insulation resistance test showed the coils are operating safely. Taking these matters into consideration and to assure reliable operation for the next 40 years, the stator coil is better to be replaced.

ix. Unit 9

Operating hours since the commissioning up to the end of 2011: 100,223 hours

Number of start/stop: 3,301

x. Unit 10

Operating hours since the commissioning up to the end of 2011: 90,364 hours

Number of start/stop: 3,260

As for units 9 and 10, Stator coils for this unit are quite new, thus replacement is not required.

(2) Study of Other Parts of Generators (Other than Stator Coil)

Other parts were also studied whether rehabilitation/replacement is necessary or not.

1) Units 1 to 4

i. Stator

Core: As these are beyond their typical life, the core should be replaced.

Frame: All frames should be replaced.

Stator foundation should be inspected. There are some small cracks on the concrete below the stator. Foundation bolts should also be inspected.

ii. Rotor

Field poles and field windings should be replaced, although the F/S report mentioned they can be reused. The reason is that they are beyond their typical life.

Top and bottom insulation collars, pole keys, pole leads, and damper connectors should also be replaced.

Other small parts will be decided after inspection at the detailed design stage such as non-destructive examination.

It is necessary to inspect rim plates and shrink keys at the detailed design stage and decide whether re-stacking is needed or not.

iii. Thrust and Guide Bearing

The thrust and guide bearing are in good condition.

iv. Brakes and Jacks

Brake and jack are required to be replaced newly.

v. Generator Cooling System

Air coolers, all RTDs, and piping material inside of air housing should be replaced.

vi. Generator Brush Assembly and Collector Rings

The static excitation system is recommended instead of the existing rotating excitation system, the generator brush and collector rings should be replaced with new ones, including the upper shaft.

In case these parts will remain in their existing positions to keep the generator flywheel effect, the collector ring and brush holder should be replaced.

vii. Generator Main Leads

Most of the parts can be used with some rehabilitation such as re-insulation or improvement of contact conditions. Flexible connectors should be replaced.

viii. Excitation System

As the existing system is rather obsolete system, this should be replaced with static digital excitation system.

ix. Generator Main Bus (Isolated Phase Bus)

Some tests such as insulation resistance measurement and bus resistance measurement, or other systemic tests, are necessary but they seem to be reused.

2) Units 5 and 6

- Major short circuit happened and design of upper guide bearing need to be changed.
- Both coils for Units 5 and 6 were damaged and replaced with non-original manufacturer's coil.

3) Units 7 and 8

i. Stator

Winding : As this will soon reach the typical life expectancy, windings should be replaced. But priority is not so high.

Core : Core should be replaced due to the same reason as mentioned above.

Frame : All frames should be replaced.

ii. Rotor

Field poles and field windings are still in good condition, so they can be reused after re-insulation.

It is possible to reuse most of the other parts.

iii. Thrust and Guide Bearings

Thrust and guide bearings are in good condition.

iv. Brakes and Jacks

Brake and jack are required to be replaced newly.

v. Generator Cooling System

Air coolers, all RTDs, and piping material inside of air housing should be replaced.

vi. Generator Brush Assembly and Collector Rings

Brush holder, although apparently in good condition, are old finger-type brush holders and should be replaced with new ones.

Most of other parts can be used with some rehabilitation.

vii. Generator Main Leads

Most of the parts can be used with some rehabilitation such as re-insulation or improvement of contact conditions.

Flexible connectors should be inspected and replaced, if necessary.

viii. Excitation System

It may be possible to reuse, but for highest reliability the voltage regulator should be the digital type to eliminate analog component drift.

ix. Generator Main Bus (Isolated Phase Bus)

Some tests such as insulation resistance measurement, bus resistance measurement, or other systemic tests, are necessary but they seem to be reused.

4) Units 9 and 10

i. Stator

To assure reliable operation for the next 40 years, the stator winding needs to be replaced in next 10 to 15 years.

ii. Rotor

Most of the parts are possible to reuse.

iii. Thrust and Guide Bearing

The thrust and guide bearing are in good condition.

iv. Brakes and jacks

Brake and jack are required to be replaced newly.

v. Generator Cooling System

For every cooler, one RTD for measuring the inlet air temperature and one RTD to measure the exhaust air temperature should be installed.

Air coolers and piping material inside of air housing should be replaced.

vi. Generator Brush Assembly and Collector Rings

All the parts can be reused.

vii. Generator Main Leads

The generator main leads are suitable to reuse.

viii. Excitation System

Due to problematic AVRs these units were started for peaking and shut down afterwards. Therefore, the number of start/stop for these units is rather high than any other units.

ix. Generator Main Bus (Isolated Phase Bus)

The generator main bus is suitable for reuse.

5.2.2 Study on Enhancement of Generator

(1) Units 1 to 4

The replacement of stator coils is recommended as mentioned above in Section 5.1 whether enhancement is considered or not. Aside from the stator coil, other parts required to be replaced are given below. More parts other than just rehabilitation are added here, which are required to be replaced due to increase in weight of the generator.

i. Stator

   All parts such as winding (coil) and core should be replaced. Stator foundation should be inspected. There are some small cracks on the concrete below the stator.

ii. Rotor

   Only the rotor spider and rim plates can be used and other parts such as poles and field winding should be replaced due to the increase in current.

iii. Brakes and Jacks

   Brake and jack are required to be replaced newly.

iv. Generator Cooling System

   The following parts should be replaced: air coolers, all RTDs, and piping material inside of air housing.

v. Generator Brush Assembly and Collector Rings

   According to the capacity increase, the excitation system will also be upgraded, and static excitation system is recommended. Furthermore, a new upper shaft with collector rings should be provided.

   In case the existing DC exciter will remain in its position to keep the generator flywheel effect, the collector ring and brush holder should be replaced.

vi. Generator Main Leads

   According to the capacity increase, the main leads must also be upgraded, therefore replacement is necessary.

vii. Excitation System

   According to the capacity increase, the excitation system must be upgraded, and static excitation system is recommended. Furthermore, a new upper shaft with collector rings should be provided.

viii. Generator Main Bus (Isolated Phase Bus)

   According to the capacity increase, the current rating must be increased, therefore this should be replaced with upgraded IPB.

ix. Guide and Thrust Bearing

   According to the weight increase, the guide bearing, thrust bearing, and thrust runner (which is mounted on the rotor) should be replaced.

(2) Units 5 and 6

The Survey Team recommended the replacement of all parts for Units 5 and 6 due to the reasons mentioned above in Sub-section 3.2.3 and the following:

- Major short circuit happened and design of the upper guide bearing needs to be changed.
- Unit 5 is operating with only limited output.
- Both coils for Units 5 and 6 were damaged and replaced with non-original manufacturer's coil.

It is further recommended that design of the guide bearing should be changed to reduce oil splashes.

(3) Units 7 and 8

Same as Units 1 to 4, when these units are required to be upgraded.

(4) Units 9 and 10

Same as Units 5 and 6, when these units are required to be upgraded.

5.3 Control and Protection

5.3.1 General

(1) Selection criteria of aimed facilities

Upgrading of units will replace the governors, automatic voltage regulator (AVRs), and associated auxiliary equipment with turbines, generators, and step-up transformers. New control, protection, and interface circuits among them should be installed.

5.3.2 Control and Protection for Generation Units

(1) Components of Control System

The Survey Team recommended that the control system will be replaced from the conventional wired logic circuit with programmable logic controller (PLC) and supervisory control and data accusation system (SCADA), which is the same option as in the F/S.

1) Unit Local Control Panel (Cubicle)

The PLCs will be equipped in the unit local control panels. This panel performs to control the turbines and generators automatically through the governor /turbine control cabinets, and AVR/generators cabinets. The PLCs are linked to SCADA in the control room for remote control. All of the field data are collected to the PLCs, then the PLCs will send the collected data to SCADA through a network.

2) Programmable Logic Controller (PLC)

The PLC performs the functions instead of the conventional wired logic sequence control circuit, and additionally, will implement the automatic units control functions.

3) Touch Panel

Local control panels will have touch panels, which perform the human machine interfaces instead of conventional indicators and switches. The touch panel will show the status of units and measurement values on the LCD.

4) Units SCADA (Supervisory Control and Data Accusation system)

This SCADA consists of PLC SCADA servers (data server), human machine interface (HMIs), engineering work station, and network switches. It is not a SCADA system for grid system control. It controls and supervises the turbine and generator from the control room instead of actual conventional turbine control desks, and generator and switchyard control desks. The SCADA system is based on the PCs (personal computers).

5) HMI

This is a human interface device between the operator and SCADA control system. The HMIs' screen (LCD) shows the status and condition of turbines, generators, step-up transformers, and such associated auxiliary equipment. The HMI receives the operator's control command for the turbine and generator via a keyboard or a mouse. It is prepared for each generation unit.

6) PLC SCADA Server (PC)

This is a data server between the HMIs and PLCs. The operator's commands are written in the database, and this database is read by the PLC. Collected status and measured value by the PLC is transferred to the PLC SCADA server, written in the database, and read by the HMIs.

7) Historical Event Recorder Function

This function chronologically arranges and shows the occurring events and troubles on the screens (LCD) or printers.

8) Periodical Data Report Function

This function performs to arrange and print the measured data such as energy production, water discharge, voltage, and current per day, week, or month.

9) Engineering Work Station (PC)

This computer is used for SCADA system maintenance. A system administrator can change the system parameters and troubles are analyzed through this computer.

10) Automatic Synchronizer

Actually, two sets of automatic synchronizer are used for ten units. These synchronizers are also old, and the VT signal selection circuit is complicated.

Automatic synchronizer for upgrading units will have an independent automatic synchronizer for each two units. (e.g., Units 1 and 2, Units 3 and 4)

i) This modification can be able to revise and adjust the synchronizing circuits without interruption of the synchronization of another unit.
ii) Circuit breaker closing and generator voltage and speed adjustment parameters can be adjusted per each two units.
iii) The cost of an automatic synchronizer is actually not high.

(2) Protection Relay System

The Survey Team recommended replacing the conventional protection relays with digital relays, which is the same option as in the F/S.

5.3.3 Control and Protection for Switchyard

(1) Opinion of the Survey Team about the Switchyard Control and Protection

The control and protection of transmission lines should be designed with unified philosophy between both ends of stations. Therefore, planning should be a concern of the NTDC/NPCC and opposite side stations.

(2) Control

Mainly, the control and protection system consists of conventional wired logic sequence circuits. The indicators, auxiliary relays, and wires are still used from the original installed condition. The circuit control function will be maintained as the original.

(3) Protection

Actually, generator feeder line protections are installed with the same protection panels of transmission lines, which are connected with the same bays of feeder lines. The function of the feeder protection (over current and unit differential relays) will be implemented in the new generator unit protection systems.

(4) Resetting Parameters for Actual Protection Relays

The set values and parameters of protections relays as bus protection, CB failures, feeder line protections will be required to change.

The protection relays will not be changed by the Project. The modified circuits and cable relocation are required, which are consequences of the generator feeders' relocation. These will be implemented by the Project.

(5) Relocation of Generator Feeders

The control and protection circuit modification for the generator feeder lines will be required in the generator upgrade.

(6) Summary Table of Transmission Line Equipment

In the case of the upgraded generator is 150 MW (PF=0.8), its step-up transformer's capacity will be more than 187 MV control and protection system. The rated current is around 820 ampere (A) at 132 kV circuit, and 410 (A) at 220 kV circuit. Current transformer (CT) ratios for the system should also be changed.

Consideration for interruptible short circuit currents of the circuit breakers should also be studied against the generator upgrading.

(7) Requirement of Modification for Switchyard SCADA

The program or parameter of SCADA should be modified to adapt to the relocated generator feeders and station service transformers' locations. The generator feeders CTs ratios will be changed, and the measuring program will also require modification.

For more effective supervision of the power station, data exchange via LAN will be requested for this SCADA and generating unit SCADAs.

5.3.4 Protection and Control System for Station Service

(1) Necessity of Low Voltage (415 V) Circuit Modification

The F/S report's alternative plans also required low voltage-side modification. Low voltage circuit modification requires further study of actual circuits.

(2) Appurtenant Work

The replacement of low-voltage circuit cables and mold circuit breakers which are installed and connected to "the motor control center cabinets for turbine and generator auxiliary equipment" are also required with the upgrading of such facilities.

(3) Service Circuit Breakers of 11kV Station

Actually, there are a total 26 sets of 11 kV circuits; 24 sets of oil circuit breaker (OCBs) and two sets of vacuum circuit breakers (VCBs) were installed recently.

5.4 Switchyard

5.4.1 Study on Rehabilitation and Enhancement of Switchyard

To lessen the power flow from 220 kV to 132 kV in the switchyard, the generators' connections to 132 kV and 220 kV are required to be modified.

In the rehabilitation and enhancement project, the step-up transformers for the subject units shall be replaced by new ones to meet the enhanced capacity of 180 MVA, which is now 138 MVA for Units 1 to 4 and 144 MVA for Units 6 to 10.

5.5 Civil Works

5.5.1 Structure Reinforcement and Improvement

For the turbine and generator foundation, the diagnosis test for concrete strength by Schmidt Hummer was carried out on 27 February 2012. In general, a crack with less than 0.3 mm is a hair crack and not harmful to the structure even without any countermeasure.

The result of investigation revealed that a crack has occurred around the penstock with more than 5 mm width slanted at Units 5 and 6, which is necessary for urgently repair with epoxy injection and carbon fiber sheet. WAPDA is consistently observing the crack in order to confirm the movement such as enlargement or slip, however, some observation data are available at the power station but not in all facilities. Actually, the foundation needs to be replaced by new high-strength concrete up to the portion of the crack. Replacement is not possible because there are adjacent equipment such as the turbine and generator. Therefore, reinforcement using epoxy injection and carbon fiber sheet shall be recommended.

The Survey Team recommends introducing a three-dimensional (3-D) measurement for grasping the present conditions and analyzing the transition of the existing cracks. These data can be utilized to map out the appropriate countermeasures against the existing cracks and large-sized earthquake in the future.

5.6 Rehabilitation and Enhancement Scenarios

5.6.1 Review of Maximum Output of Turbine and Generator

In the review of the scenarios for rehabilitation and enhancement through the Project, the Survey Team has calculated the maximum turbine output in consideration of the raising of Mangla Dam, as follows:

(1) Reservoir water level after dam raising : EL 1,242 ft (378.8 m)
Tailrace water level : EL 836 ft (255.0 m)

Gross head at maximum output : 123.8 m

(2) Each unit maximum allowable discharge capacity : 4,900 cfs (138.7 m^3/s)

(3) 1) Head loss at intake tunnel for 9,800 cfs : 10.3 ft (3.14 m)

2) Head loss at trashracks for 9,800 cfs : 2.0 ft (0.61 m)

3) Head loss at bi-plane type inlet valve for 4,900 cfs : 1.83 ft (0.56 m)

Note: Head loss in case of butterfly-type inlet valve is 2.76 ft (0.84 m)

(4) Effective head at maximum output

= Gross head – Head losses

= 123.8 m – (3.14+0.61+0.56) m = 119.5 m

The turbine maximum output will be calculated as follows;

P max = 9.8 * Q at P max * H at P max * η T KW

Where Q at P max = 138.7 m^3/s

H at P max = 119.5 m

η T = 93.0% (Estimated turbine efficiency at P max)

<u>Therefore P max = 151.1 MW</u>

Based on the above maximum turbine output, the Survey Team recommended the rehabilitation and enhancement concept of the Project as follows:

(1) Main recommendation by the Survey Team is:

1) Generator's Capacity: Enhancement up to 180 MVA/unit from the existing 125 MVA/unit

2) Output: Enhancement up to 144 MW/unit with 0.8 power factor

(2) Main difference compared with the F/S report is that the Survey Team's idea does not include modification of the existing concrete foundation of turbines and generators.

The basic feature of the turbine and generator as existing and after enhancement is shown in Table-5-11.

5.6.2 Priority of Rehabilitation and Enhancement

(1) Priority of Turbine Rehabilitation

Considering the duration of the unit operation and numbers of repair for the turbine runner and associated equipment present conditions, the replacement or rehabilitation is recommended as shown in the following Table 5-3.

Table 5-3 Priority of Rehabilitation of Turbine

Unit	Inlet Valve	Runner	Governor	Other Equipment
1 to 4	Leakage water from valve packing to turbine is extremely high and leakage water at pipe connection is also very high. Prior to rehabilitation of turbine, rehabilitation or replacement of inlet valve shall be done.	Repair welding of each runner is done every 2 or 3 years after starting operation. The repair welding in Japan is limited for 3 times to prevent breakage. Total number of re-welding is more than 10 times and preferable to replace to a new runner.	Mechanical type governor is operating and the manufacturing of this type had been suspended long time ago. Therefore, spare parts supply is not available together with maintenance engineers. So, replacement of the governor system is required.	The wired damages and rust shall be repaired and overhaul of the irrigation valve is required for further long time operation. Measuring instrument and electrical wiring shall be replaced for getting maintenance data in the new control system.
5 and 6	Same as above	For getting good characteristics turbine, replacement of turbine major parts is required.	Same as left	Same as above
7 and 8	Still good condition	Still good condition	Still good condition	Still good condition
9 and 10	Still good condition	Still good condition	Still good condition	Still good condition

Source: Prepared by the Survey Team

From the above table, rehabilitation or replacement of inlet valve, runner, governor, and irrigation valve for Units 1 to 6 is urgently required.

(2) Priority of Generator Rehabilitation

The following Table 5-4 is the summary of the generator's current condition from the study of rehabilitation in Sub-section 5.2.1, and shows the priority of rehabilitation.

Table 5-4 Priority of Rehabilitation of Generator

Unit No.	Analysis by N-Y Map	Analysis by Insulation Resistance Measurement	Analysis by Past Fault/Incident	Judgment
1 to 4	Stator winding is already beyond the typical life expectancy	Still Good	-	Urgent rehabilitation is necessary
5 and 6	Fault/incident of the winding occurred some times (As some windings have been replaced, analysis by N-Y map cannot be conducted)	Still Good	Fault/incident occurred frequently in the past.	Urgent rehabilitation is necessary

7 and 8	Stator winding is in the last stage of life, but priority is not so high	Still Good	-	Rehabilitation is necessary, but priority is not so high
9 and 10	Stator winding is quite new, as compared to other units	Still Good	-	Rehabilitation is necessary, but priority is not so high

Source: Prepared by the Survey Team

5.6.3 Expected Increased Amount of Power Generation

The Survey Team has calculated the annual power generation which is expected to be increased by the implementation of the Project.

The annual power generation of the existing power plant in Mangla Power Station in the period from 2001 to 2010 for the past ten (10) years is shown in the following table. The average annual power generation for the pat 10 years is calculated to be 5,000.1 [GWh].

(1) Annual Power Generation for Scenario A (for 4 units)

The annual power generation after the implementation of Scenario A, which will be enhanced up to 1,266 MW in total from the existing 1,150 MW, in the period from 2012 to 2053 for 42 years is shown in the following table. The average annual power generation is calculated to be 6,585.9 GWh which is added 1,585.8 GWh from 5,000.1 GWh of the existing plant. The said incremental energy is expected to cover about 892,000 households.

(2) Annual Power Generation for Scenario B (for 6 units)

The annual power generation after the implementation of Scenario B, which will be enhanced up to 1,324 MW in total from the existing 1,150 MW, in the period from 2012 to 2053 for 42 years is shown in the following table. The average annual power generation is calculated to be 6,660.8 GWh which is added 1,660.7 GWh from the existing plant. The said incremental energy is expected to cover about 934,000 households.

5.6.4 Recommendation in the F/S Report

As described in the previous clauses in this chapter, the Survey Team has proposed the rehabilitation and enhancement of generators to increase their capability up to 144 MW per unit at PF 0.8 (rated capacity is 180 MVA), instead of the existing one which has a capability of 115 MW (rated capacity is 125 MVA), on the condition that the existing concrete foundations are to be used without rehabilitation. Meanwhile, in the F/S report, it is recommended to rehabilitate and enhance the generator for upgrade up to 135 MW per unit at PF 0.8 (rated capacity is 169 MVA).

The Survey Team has reviewed the recommended idea in the F/S report, in particular, from the technical aspects as below.

(1) Annual Power Generation for Scenario A (for 4 units)

The annual power generation after the implementation of Scenario A, which will be enhanced up to 1,230 MW in total (enhancement of 4 generators up to 135 MW) from the existing 1,150 MW, in the period from 2012 to 2053 for 42 years is shown in the following table. The average annual power generation is calculated to be 6,532.6 GWh which is added 1,532.5 GWh from 5,000.1 GWh of the existing plant. The said incremental energy is expected to cover about 862,000 households.

(2) Annual Power Generation for Scenario B (for 6 units)

The annual power generation after the implementation of Scenario B, which will be enhanced up to 1,270 MW (enhancement of 6 generators up to 135 MW) in total from the existing 1,150 MW, in the period from 2012 to 2053 for 42 years is shown in the following table. The average annual power generation is calculated to be 6,588.4 GWh which is added 1,588.3 GWh from the existing plant. The said incremental energy is expected to cover about 894,000 households.

(3) Comparison with Generator’s Output of 144MW and 135 MW

As the result of above calculations on annual power generation, it reveals that the generator’s output of 144MW per unit is more advantageous than 135MW at the average annual power generation. However, in case of 144 MW, the expected number of days which would be reached the maximum output of 1,266MW (4 units enhancement) and 1,324MW (6 units enhancement) is limited to 65 days and 54 days respectively due to the restriction of water resources which are stored to Mangla Dam. Thereby, the average plant factor of 144MW, which is defined as the ratio of the average power load of a power plant to its rated capacity, is lower than 135MW.

It means that the generator's output with 135 MW is more advantageous in respect of a cost benefit compared to 144MW, and it can be said that economical efficiency in case of 135MW is higher than 144MW.

Therefore, the Survey Team also can recommend the rehabilitation and enhancement concept with generator's output of 135 MW per unit with 0.8 power factor in accordance with the recommendation in the F/S report, and the subsequent review of this chapter is carried out based on it.

Incidentally, the Survey Team has judged that there is no any change on the result of technical reviews mentioned in the preceding clauses by adopting the generator's output 135 MW per unit instead of 144 MW, except the capacity of main transformer which is changed to 169 MW instead of 180 MVA which is described in Sub-clause 5.4.1.

5.6.5 Study on Superiority of Japanese Technology

The Survey Team reviewed the superiority of water turbine generator products manufactured by Japanese manufacturing firms compared to those of other overseas manufacturers in order to formulate the Project as a STEP Yen loan.

However, it is considered that there is no broad distinction between Japanese and the overseas manufacturers in terms of technical capability to meet the requirement of rehabilitation and enhancement proposed in this study.

Therefore, the superiority of Japanese manufacturers is explained from the viewpoint of "reliability of equipment" based on past operating records at Mangla Power Station, which were provided by WAPDA through this preliminary survey.

(1) Annual Power Generation and Operating Ratio

Based on the actual data of annual power generation and operating hours of each unit of water turbine generator from the commissioning date up to December 31, 2011, the average annual power generation and operating ratio were calculated.

As indicated in the above table, the average annual power generation of each unit is calculated below:

- Units 1 to 4 (both turbine and generator are Japanese products): 581 [GWh/year]
- Units 7 & 8 (turbine is an overseas product and generator is Japanese product): 492 [GWh/year]
- Units 5 & 6, 9 & 10 (both turbine and generator are overseas products): 436 [GWh/year]

The operating ratio of each unit is also calculated below:

- Units 1 to 4: 81.3 [%]
- Units 7 & 8: 68.2 [%]

- Units 5 & 6, 9 & 10: 69.7 [%]

(2) Fault Record

Regarding Units 1 to 4, 7 and 8, the Survey Team confirmed that any failure or trouble affecting the generating capability or functions of the water turbine generator has not occurred from the commissioning date up to present.

On the other hand, for Units 5 and 6, the damages of the stator winding, stator core and field winding of generator has been occurring frequently. Since the first failure occurred in 1990, similar failures have occurred six times with stoppage of a generator for a total of 20 months. Unit 6 has had five times failures with stoppage of generator for a total of 12 months since the first failure occurred in 1985.

In addition, despite the short operating period which is less than 20 years, Units 9 and 10 recorded the lowest operating ratio in all units. Unit 9 was 54.93% and Unit 10 was 51.57%, due to the fault of AVR (automatic voltage regulator) of the exciter causing frequent irregular trips.

5.6.6 Study on Possibility of Formulating the Project as STEP Loan

The Japanese products of water turbine generator have superiority from the viewpoint of "Reliability of Equipment", however, there is no remarkable distinction of technical aspects between the Japanese manufacturers and the overseas ones. Therefore, it seems have a low potential for the formulating the Project as STEP loan.

In case the Project is implemented by general untied Japanese ODA loans instead of STEP loan, the Survey Team recommends the following measures in order to maintain the high quality and performance of the Project which is envisaged in this study:

(1) The Tenderer shall meet the following requirements as the qualification of Tenderer.

1) experience of rehabilitation project of hydropower station on same scale of Mangla Power Station and except for own country
2) experience of rehabilitation project of hydropower station with other company’s products
3) actual performance for safety operation more than 5 years after rehabilitation project
4) experience of project funded by JICA, JBIC, World Bank and ADB

(2) Burden of Expense on Reverse Engineering

The cost for the reverse engineering shall be born by the Contractor including the electrical tariff to compensate the stoppage of water turbine generator for the reverse engineering by the Contractor. The said cost shall be evaluated at the cost evaluation stage.

(3) Life Cycle Cost (LCC)

A life style cost (LCC) consists of certain portion, which is operation cost and fuel cost, and uncertain portion such as replacement cost of equipment, or expenses for replacement with spare parts.

The comprehensive evaluation at the cost evaluation stage shall be considered the LCC, which consists of maintenance cost (equipment cost, installation cost, personnel expenses, etc.) and stoppage duration of water turbine generator required for maintenance, for 10 years operation after commissioning.

In addition, the Tenderers shall calculate a monetary loss caused by unscheduled shutdown due to any failure or damage of the equipment based on past actual performance owned by each Tenderer. As for the Tenderers who could not prove their past performance for 35 years operation, the Tender Documents shall stipulate the calculation methods for such Tenderers, for example, the determined sum of the cost shall be added in their tender price.

CHAPTER 6 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

6.1 Environmental and Social Considerations

6.1.1 Necessity of an IEE or EIA

Interpreted with the advice of the Environment Cell of WAPDA and international standard context as well as Japanese concerned regulations, Article 12 of PEPA, 1997 requires application of EIA for new project where new installation of facility or physical structure are commenced, as well as for the one that is likely to cause an adverse environmental effects.

The concerned Project does not fall in the category of new project, but project of rehabilitation (as refurbishment) and enhancement (as up-gradation) of existing facility inside Mangla Power Station. Therefore, neither IEE nor EIA are supposed to be applied to this Project.

However, Schedule I and II in Pakistan EPA (Review of IEE and EIA) Regulations, 2000 does not specify the project type clear and distinct enough to distinguish between new and rehabilitation project, in respect where Japanese corresponding regulations distinctively define those. If only project size is counted, the concerned Project would fall under Schedule II which means that EIA is required since the Project will enhance the capacity of generation by 116 MW to 174 MW. Further, Article 5 of the above Regulation 2000 gives the Federal Agency, namely Pakistan Environmental Protection Agency (Pak-EPA), the authority of judging IEE/EIA requirement.

Considering these, WAPDA should consult with Pak-EPA and prepare the necessary filing to follow their instruction as required, before the next step of the study.

6.1.2 Environmental Evaluation

In this section, possible environmental and social impacts regarding the project activities of overhaul, repair and replacement are briefly identified. Accordingly, corresponding mitigation measures are also examined where and when required. Examinations here are based on the JICA Guidelines for Environmental and Social Considerations (April 2010), the discussions with the Environmental Cell of WAPDA, the survey at Mangla Power Station, the environmental review of the FS report for Mangla Refurbishment Project by WAPDA (hereinafter referred to as the FS report) and other legal review of Pakistan EPA (Environmental Protection Agency).

The following are the impacts and mitigation measures examined:

1) Water use for other purpose

Impacts

There will be no change of water flow downstream due to the rehabilitation project. Irrigation water is secured on first priority regardless of the project, by the given rules with AJK-Government, according to both Environmental Cell and Mangla Power Station Office of WAPDA.

Mitigation

No mitigation measures are required for this purpose since no impacts are expected.

2) Water quality

Impacts

During procurement as well as operation, spilling and leakage of lubricants, oils and other petroleum products may occur.

Mitigation

Monitoring of effluent water quality discharged from the sewage system of the power station should be conducted on quarterly basis or more if necessary.

To avoid pollution of ground and surface water by spilling and leakage of lubricants, oils, and other petroleum products, the some measures are recommended.

3) Noise, vibration, and dust emission during construction works for replacement.

Impacts

There will be no environmental significant impacts of noise, vibration, and dust through the rehabilitation and replacement works since the existing power station is sufficiently distant from the inhabited area and a good network of paved access road from the trunk road to the project site already exists.

Mitigation

- No mitigation for noise, vibration, and dust is necessary for residential quarters since the project site (power station) is at least a few kilometers away from the nearest inhabited area.
- Noise and vibration should be controlled by distance and barrier of noise-absorbing material. It should be controlled below 80 dBA (from 1 meter at the source) according to the FS report.

4) Solid Waste

Impacts

An amount of solid waste will be generated from dismantled units that will consist of hazardous and non-hazardous waste. Inappropriate disposal of hazardous and non-hazardous waste may cause significant adverse impact on the local environment.

Mitigation

Hazardous and non-hazardous waste should be handled separately in disposal.

- Those separately treated solid waste should be safely disposed only in demarcated waste disposal sites.
- Precautionary planning of solid waste management prior to implementation of dismantling work is recommended.

5) Other impacts during construction (rehabilitation and replacement).

Impacts

i) Movement of heavy machine and equipment for installation

ii) Construction camp and worker-related issues

iii) Workers exposure to hazardous materials and other safety risks during dismantling stage of old equipment

Mitigation

i) Movement of heavy machine and equipment for installation

ii) Construction camp and worker-related issues

The best mitigation measures should be not setting up any construction camp. If it cannot be avoided, the following measures need to be taken.

iii) Workers exposure to hazardous materials and other safety risks

6.1.3 Environmental Management

(1) Water Quality Management

(2) Treatment or Management of Hazardous Waste Oil and Material

6.2 Project Impact on GHG Emission Reduction

The project intends to directly contribute to GHG emission reduction through hydropower plants rehabilitation and enhancement aiming to generate renewable energy, which does not emit GHG at generation, with the use of hydropower.

This section made an estimation for project impact on GHG emission reduction, with available data of WAPDA and calculation with JICA Climate Finance Impact Tool (Mitigation) Draft Ver. 1.0, June 2011, on mitigation-17-hydro sector.

6.2.1 Methodology on Emission Reduction

The GHG emission reduction through hydropower is determined as the difference between baseline emissions (GHG emissions with the power generation of fossil fuel that will be replaced by enhanced hydropower of the Project) and project emissions after project activity of hydropower plants enhancement. The formula is as follows.

$$ER_y = BE_y - PE_y \ (t\text{-}CO2/y)$$

- ***ERy***: GHG emissions reduction in year y achieved by the project (t-CO2/y)
- ***BEy***: GHG emissions at fossil fired power plants in year y (t-CO2/y) (Baseline emission)
- ***PEy***: GHG emissions after running hydro pow

6.2.2 Scenarios of Rehabilitation and Enhancement

Project impacts on GHG emission reduction are calculated for the following two scenarios that are proposed in Chapter 5 as well as for the individual unit.

Table 6-1 Scenarios of Rehabilitation and Enhancement

Scenarios	Unit
Scenario-A	Unit 1,2,3, & 4
Scenario-B	Unit 1,2,3,4,5, & 6

6.2.3 Quantity of Electricity to be Increased after Project Implementation

For each unit, the capacity of generation will be enhanced from 115 MW to 135 MW. Then, the quantity of electricity to be increased after project implementation (EGpj,y) is the following, with respect to each scenario.

Scenario-A: With 4 units enhanced, the total increase of generation will be 80 MW and 1,532.5 GWh annually.

Scenario-B: With 6 units enhanced, the total increase of generation will be 120 MW and 1,588.3 GWh annually.

6.2.4 GHG Emission Reduction after Project Activity

The following are the results of the calculation for GHG emission reduction after the Mangla Power Station Rehabilitation and Enhancement Project.

(1) Scenario-A (With 4 units enhanced)

1) Scenario-A: Baseline emission

BEy = ΣFCi × conversion factor (41.868：TJ/ktoe) × COEFi

BE_y	Baseline emission: GHG emission associated with fuel consumption which is assumed to be replaced by hydropower generation	1,472,452	t-CO_2/y
FC_i	Reduction of fuel type I consumption in scope of reduction	-	ktoe/y
	Crude oil	454	ktoe/y
	Gas	0	ktoe/y
	Coal	0	ktoe/y
	Others	0	ktoe/y
$COEF_i$	CO_2 emission factor per net calorific value of fuel type i	-	t-CO_2/TJ
	Crude oil	77.4	t-CO_2/TJ
	Gas	56.1	t-CO_2/TJ
	Coal	94.6	t-CO_2/TJ
	Others	0	t-CO_2/TJ

Source : Prepared by the Survey Team

2) Scenario-A: Project emission **PEy**

PE_y	Project emission: GHG emission after project activity	137,925	t-CO_2/y
PE_{res}	Emission from reservoirs	137,925	t-CO_2/y

Source : Prepared by the Survey Team

3) Scenario-A : GHG emission reduction after project activity **ERy** ＝**BEy** － **PEy** [t-CO2/y]

ER_y	GHG emission reduction after project activity	1,334,527	t-CO_2/y
BE_y	Baseline emission: GHG emission reduction associated with fuel consumption which is assumed to be replaced by hydropower generation	1,472,452	t-CO_2/y
PE_y	Project emission: GHG emission after project activity	137,925	t-CO_2/y

Source : Prepared by the Survey Team

GHG Emission Reduction for Scenario-A = 1,334,527 [t-CO2/y]

(2) Scenario-B (With 6 units enhanced)

1) Scenario-B: Baseline emission **BEy**

BE_y	Baseline emission: GHG emission associated with fuel consumption which is assumed to be replaced by hydropower generation	1,526,065	t-CO_2/y
FC_i	Reduction of fuel type I consumption in scope of reduction	-	ktoe/y
	Crude Oil	471	ktoe/y
	Gas	0	ktoe/y
	Coal	0	ktoe/y
	Others	0	ktoe/y
$COEF_i$	CO_2 emission factor per net calorific value of fuel type i	-	t-CO_2/y
	Crude oil	77.4	t-CO_2/y
	Gas	56.1	t-CO_2/y
	Coal	94.6	t-CO_2/y
	Others	0	t-CO_2/y

Source : Prepared by the Survey Team

2) Scenario-B: Project emission **PEy**

PE_y	Project emission: GHG emission after project activity	142,947	t-CO_2/y
PE_{res}	Emission from reservoirs	142,947	t-CO_2/y

Source : Prepared by the Survey Team

3) Scenario-B: GHG emission reduction after project activity **ERy** ＝**BEy** － **PEy** [t-CO2/y]

ER_y	GHG emission reduction after project activity	1,383,118	t-CO_2/y
BE_y	Baseline emission: GHG emission reduction associated with fuel consumption which is assumed to be replaced by hydropower generation	1,526,065	t-CO_2/y
PE_y	Project emission: GHG emission after project activity	142,947	t-CO_2/y

Source : Prepared by the Survey Team

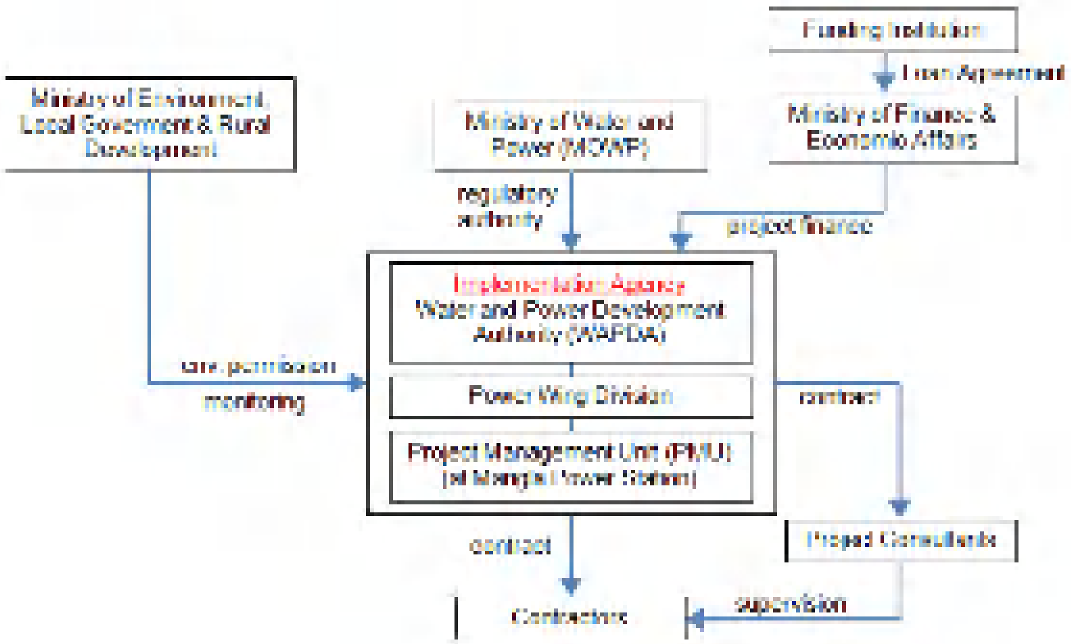
GHG Emission Reduction for Scenario-B = 1,383,118 [t-CO2/y]

CHAPTER 7 PROJECT IMPLEMENTATION PLAN

7.1 Implementation Policy

7.1.1 Implementation Process of the Project

A draft implementation process of the Project is shown in Figure 7-1:



Source: Prepared by the Survey Team

Figure 7-1 Project Implementation Process

The following are the envisioned undertakings of the implementation agency (WAPDA), consultants, and contractors of the Project:

(1) Implementation Agency

The implementation agency for the Project will be WAPDA under the supervision of the Energy Division of MOWP. It was assessed that WAPDA has enough technical capabilities to implement the Project with its abundant experiences as implementation agency for hydropower projects such as Warsak Hydropower Station, Tarbera Dam, Mangla Dam, Chashma Hydropower Station and Ghazi Barotha Hydropower station etc. In addition, WAPDA has established the structure for the development of human resources such as the Hydel Training Center Mangla.

The manpower of the project management unit (PMU) for the Project will consist of staff coming from the Power Wing Division in WAPDA Headquarter. The PMU office will be located in Mangla Power Station.

(2) Consultant

The consultant will be responsible for the activities below. Items in parentheses are the corresponding output of each activity.

1) Conduct detailed design and preparation of tender documents (Tender Documents)
2) Prepare cost estimate and time schedule (Cost Estimate and Schedule)
3) Assist the employer in the conduct of tendering process
4) Prepare pre-qualification documents (P/Q Documents)
5) Conduct tender evaluation. (Evaluation Report)
6) Assist employer to carry out contract negotiation (Contract Agreement and Minutes)
7) Review drawings for approval of equipment, materials, and construction method (Comment Letters)
8) Witness shop inspection and site inspection (Inspection Report)
9) General works regarding supervision during construction
10) Monitor progress and issue interim payment certificate (Progress/Payment Certificate)
11) Assist employer to issue taking-over certificate (Taking-over Certificate)
12) Prepare completion report (Completion Report)

(4) Contractor

The contract of the contractor for the Project will be made on a turnkey basis. Therefore, the contractors will be responsible for the following:

1) Engineering and procurement of equipment and materials related to the Project including site survey and design.
2) Shop test, packing, shipping, customs clearance and delivery to site.
3) Pre-commissioning and commissioning tests.
4) Training of WAPDA engineers at the manufacturer’s factory.
5) On-the-job training for the WAPDA engineers in the project site.
6) Maintenance of facilities during defects liability period.

7.1.2 Transportation

There are two transportation routes used in Pakistan. One is shipping to Karachi by ship and inland transportation by truck. Another one is flying to Islamabad by air cargo, and then inland transportation to Mangla by truck. A comparison table on the distances of the different landing ports is shown in Table 7-1. In the past project, the route from Karachi is generally used, however, the Survey Team recommends that the route from Karachi will be used for general cargoes and the route from Islamabad will be used for smaller items and during emergency cases.

Table 7-1 Transportation Route

Port	Conveyance	Distance to Power Station	Via
Karachi	By ship and truck	1,500 km	Hyderabad, Multan, Lahore
Islamabad	By air and truck	200 km	-

Source: Prepared by the Survey Team

7.2 Implementation Schedule

For the large scale rehabilitation and enhancement project, there are four scenarios of the implementation schedule. The basic condition of each scenario is listed below:

(1) Scenario-A1

The implementation schedule for Scenario-A1, which is the rehabilitation and enhancement of four (4) units with double unit stoppage, is shown in Figure 7-3. The total duration of the Project was estimated at 95 months from the preparation stage of JICA loan agreement to the completion of the commissioning test on-site.

(2) Scenario-A2

The implementation schedule for Scenario-A2, which is the rehabilitation and enhancement of four (4) units with single unit stoppage, is shown in Figure 7-4. The total duration of the Project was estimated at 110 months from the preparation stage of JICA loan agreement to the completion of the commissioning test on-site.

(3) Scenario-B1

The implementation schedule for Scenario-B1, which is the rehabilitation and enhancement of six (6) units with double unit stoppage, is shown in Figure 7-5. The total duration of the Project was estimated at 107 months from the preparation stage of JICA loan agreement to the completion of the commissioning test on-site.

(4) Scenario-B2

The implementation schedule for Scenario-B2, which is the rehabilitation and enhancement of six (6) units with single unit stoppage, is shown in Figure 7-6. The total duration of the Project was estimated at 132 months from the preparation stage of JICA loan agreement to the completion of the commissioning test on-site.

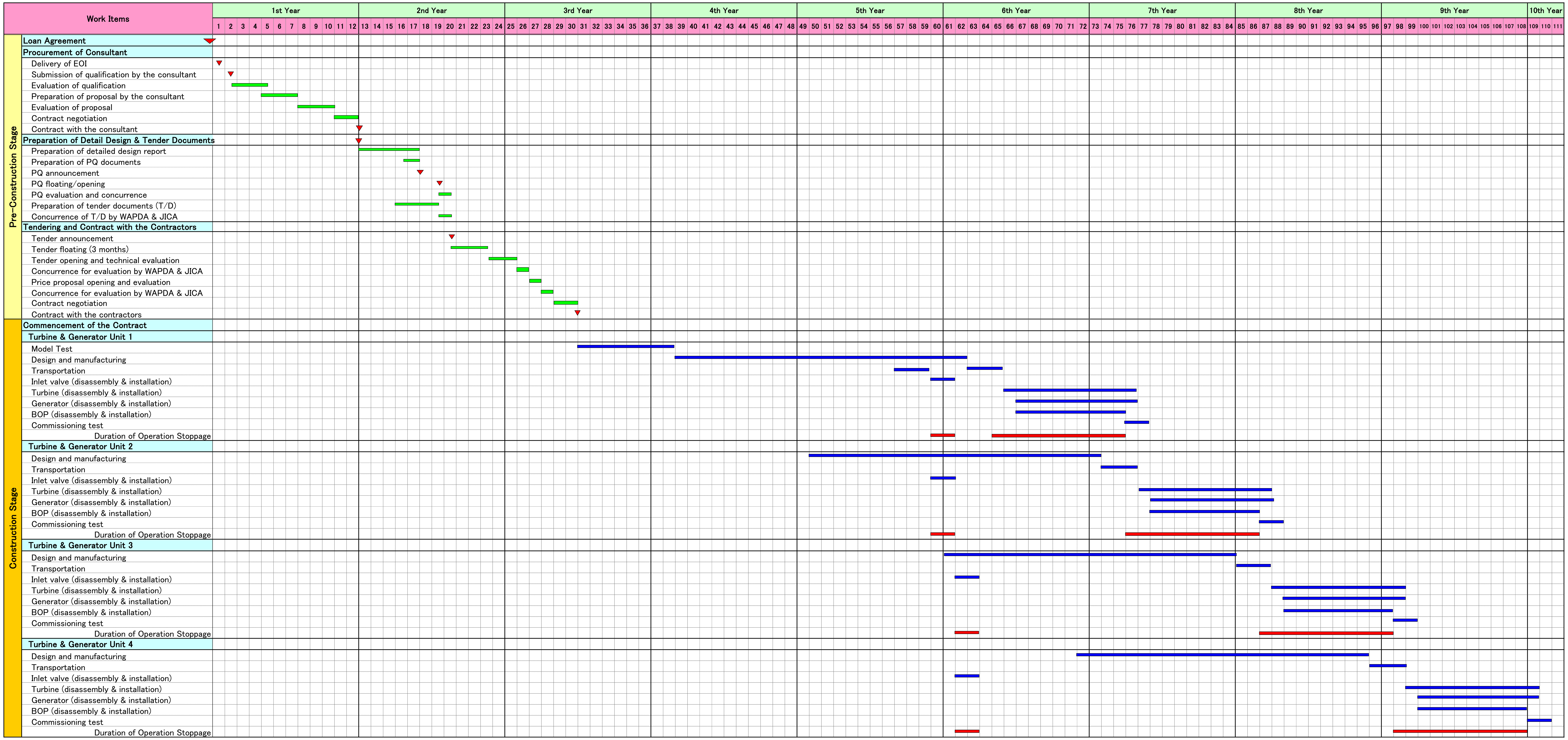
It was tentatively envisaged that the schedule for the procurement of consultant, preparation of detailed design report and tender documents, and tendering and contract with the contractor would be implemented during the following period:

- Procurement of Consultant : 12.0 months
- Preparation of Detailed Design Report and Tender Documents : 7.5 months
- Tendering and Contract with Contractor : 10.5 months

Figure 7-3 Implementation Schedule for Scenario-A1

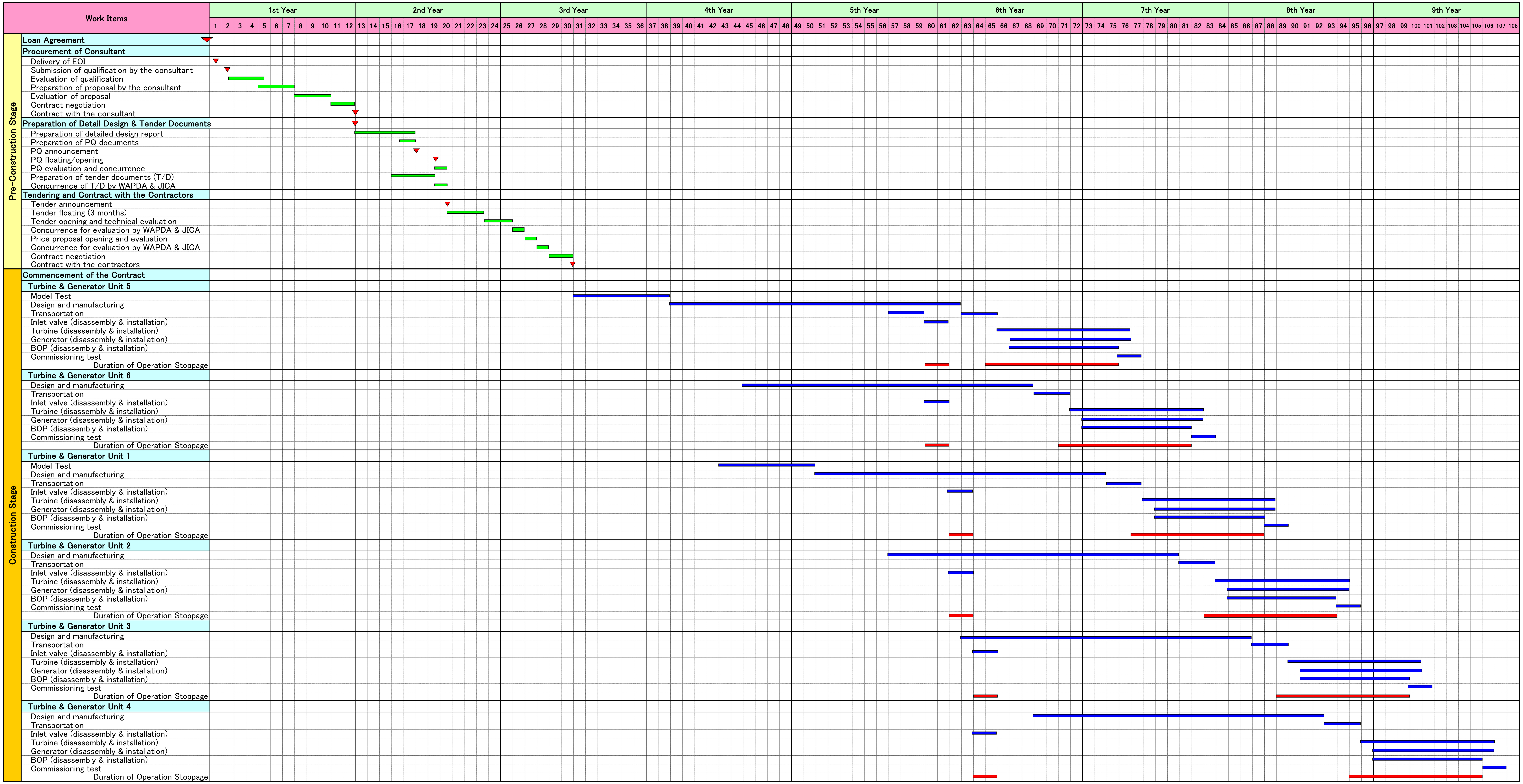
Note: Decreasing generating power caused by operational stoppage of 2 units during the construction stage of Scenario-A1 would be covered by increase of power generation of other 8 units.
However, it seems to be difficult to avoid the large lowering of total power generation of Mangla Power Station at this scenario.

Figure 7-4 Implementation Schedule for Scenario-A2



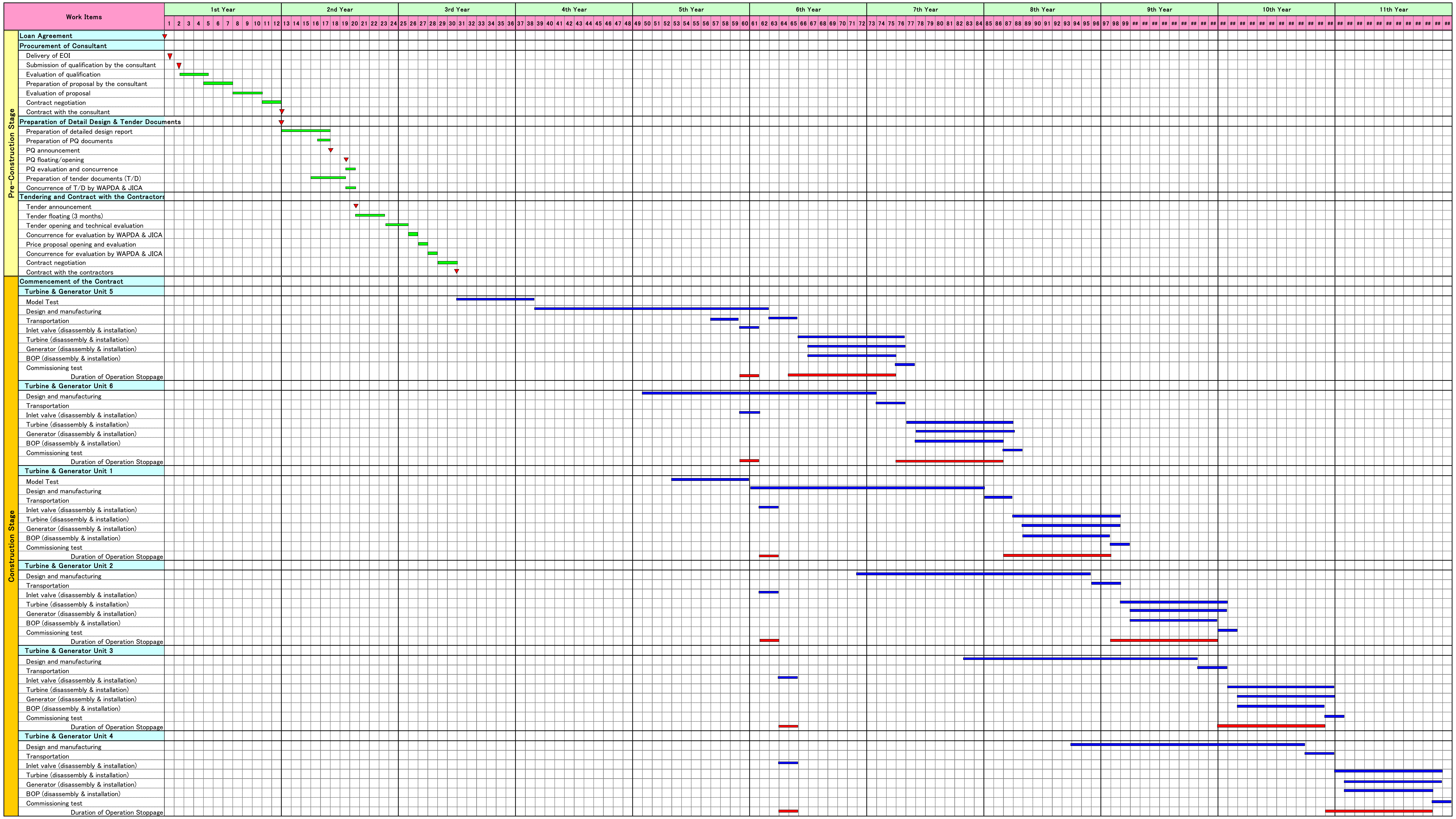
Note: Decreasing generating power caused by operational stoppage of 1 unit during the construction stage of Scenario-A2 would be minimized the total power generation of Mangla Power Station by increase of power generation of the other 9 units.

Figure 7-5 Implementation Schedule for Scenario-B1



Note: Decreasing generating power caused by operational stoppage of 2 units during the construction stage of Scenario-B1 would be covered by increase of power generation of other 8 units.
However, it seems to be difficult to avoid the large lowering of total power generation of Mangla Power Station at this scenario.

Figure 7-6 Implementation Schedule for Scenario-B2



Note: Decreasing generating power caused by operational stoppage of 1 unit during the construction stage of Scenario-B2 would be minimized the total power generation of Mangla Power Station by increase of power generation of the other 9 units.

7.3 Security Regulation in the Project Site

The Ministry of Interior (MOI) stipulates the security regulation for government-sponsored project. Their security is the main responsibility of the government. The sponsoring ministry or department must be made responsible to coordinate and ensure the safety and security of their foreign guests in collaboration with the law enforcing agencies (LEAs). The sponsor must deputize an officer to look after the security aspects and the whole blame and responsibility must not be thrown to the LEAs alone.

7.4 Required Permission for Foreigner to Enter the Project Site

The following procedures are stipulated by MOI in acquiring permission of foreigner to enter the project site in Mangla. The said permission is named as non-objection certificate (NOC).

1) The consultant or the contractor will apply to WAPDA for an issuance of NOC.
2) WAPDA requests to MOI for issuance of NOC for the consultant or the contractor.
3) MOI instructs the Administration of AJ&K, Inspected General Police (IGP) for arrangement of the security for the consultant or the contractor during their transfer to the project site in Mangla and their stay at the site.
4) MOI issues the NOC to WAPDA, and WAPDA informs the consultant and the contractor.

CHAPTER 8 PROJECT COST ESTIMATION

8.1 Estimation of Project Costs

8.1.1 Basis of Estimates

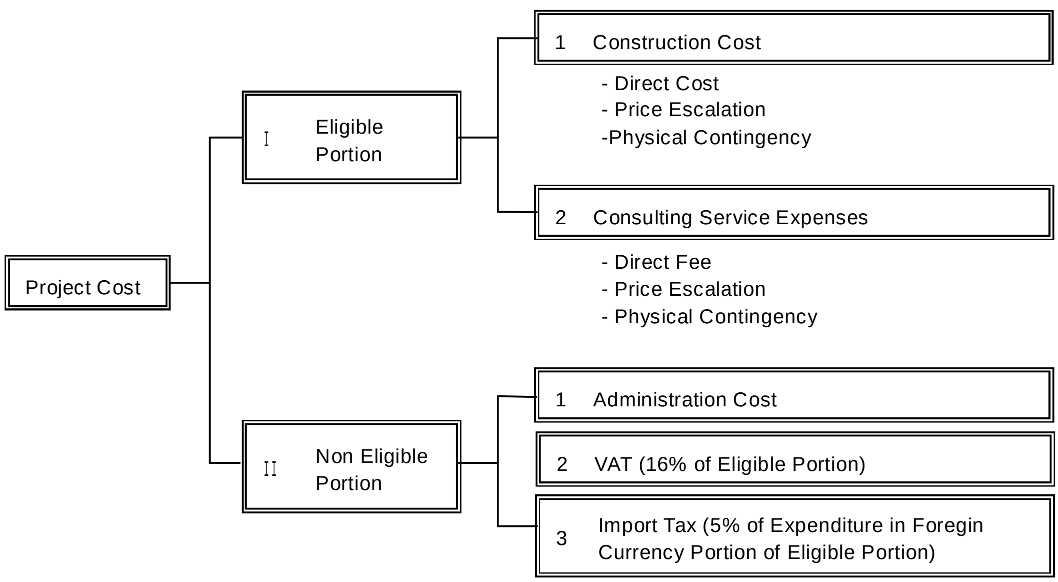
(1) Exchange Rate

The exchange rate was estimated based on a monthly average rate of November 2012. The following exchange rates were adopted:

USD 1	=	JPY 80.9
USD 1	=	PRs 96.1
JPY 1	=	PRs 0.84

(2) Composition of the Project Implementation Cost

The project cost composed of an eligible portion and non-eligible portion is shown in Figure 8-1.



Source: Prepared by the Survey Team

Figure 8-1 Composition of the Project Cost

(5) Price Escalation Rates of Foreign and Local Currencies

Price escalations were assumed to be 2.1% of the direct cost for foreign currency, and 5.7% of the direct cost for local currency, referring to similar projects.

(6) Physical Contingency

Physical contingency was assumed to be 5% of the sum of the direct cost and price escalation for construction works and consulting services.

(7) Consulting Service Expenses

The consulting service fee consisting of engineering services was estimated based on the number of man-month (MM) required for the service.

(8) Administration Cost

The administration cost was estimated based on the number of man-month (MM) required for Project Management Unit (PMU) as shown in Table 7-1.

(9) Value Added Tax (VAT)

The VAT was assumed at 16 % of the sum of both of the foreign currency portion and local currency portion of the eligible portion.

(10) Custom Duty

For national projects, the import tax of 5% was applied to the CIF prices of the costs for the procurement of materials and equipment abroad.

8.1.2 Estimated Consulting Service Fee

(1) Required M/M of the Consultant

The required input of competent consultant's engineers for each scenario is shown in Tables 8-1 and 8-2 respectively.

The definition of scenarios is as below:

- Scenario-A1: Units 1-4, double units stoppage
- Scenario-A2: Units 1-4, single unit stoppage
- Scenario-B1: Units 1-6, double units stoppage
- Scenario-B2: Units 1-6, single unit stoppage

Table 8-1 Input of Required Engineers at Scenario-A1 and Scenario-A2

Phase	Scenario-A1 (Unit 1- 4, double units stoppage)		Scenario-A2 (Unit 1- 4, single unit stoppage)	
	Foreign Engineers (M/M)	Local Engineers (M/M)	Foreign Engineers (M/M)	Local Engineers (M/M)
1. Design Stage	39	49	39	49
2. Tendering Stage	7	7	7	7
3. Construction Stage	164	217	224	223
Total	210	273	270	279

Source: Prepared by the Survey Team

Table 8-2 Input of Required Engineers at Scenario-B1 and Scenario-B2

Phase	Scenario-B1 (Unit 1- 6, double units stoppage)		Scenario-B2 (Unit 1- 6, single unit stoppage)	
	Foreign Engineers (M/M)	Local Engineers (M/M)	Foreign Engineers (M/M)	Local Engineers (M/M)
1. Design Stage	59	83	59	83
2. Tendering Stage	7	7	7	7
3. Construction Stage	216	310	316	320
Total	282	400	382	410

Source: Prepared by the Survey Team

Based on the above assumptions of the required input of engineers, the consulting service fee at Scenario-A1 and A2 during the implementation period was estimated at JPY1,035 million and JPY1,287 million respectively. The total consulting service fees at Scenario-A1 and A2 correspond to about 6.9% and 8.6% of the total direct construction cost at Scenario-A as shown in Table 8-1.

As for Scenario-B1 and B2, the consulting service fee t at the Scenario-B1 and B2 during the implementation period was estimated at JPY1,458 million and JPY1,897 million respectively. The total consulting service fees at Scenario-B1 and B2 correspond to about 5.8% and 7.6% of the total direct construction cost at Scenario-B as shown in Table 8-2.

8.1.3 Estimated Project Implementation Cost

(1) General Untied Japanese ODA Loans

1) Scenario-A1 and A2

The estimated project implementation cost at Scenarios-A1 and A2 under the condition of utilizing the general untied Japanese ODA loans, which is applied an interest rate 1.4%, is summarized in Tables 8-3 and 8-4 respectively.

Table 8-3 Project Cost at Scenario-A1 (General Untied Japanese ODA Loans)

Item		Total		
		FC	LC	Total
A. ELIGIBLE PORTION		Mil. Yen	Mil. PRs	Mil. Yen
I)	Procurement / Construction	16,784	992	17,617
	UNIT 1-4	14,403	714	15,003
	Base cost for JICA financing	14,403	714	15,003
	Price escalation	1,582	230	1,775
	Physical contingency	799	47	839
II)	Consulting services	853	216	1,035
	Base cost	737	156	867
	Price escalation	76	50	118
	Physical contingency	41	10	49
Total (I + II)		17,637	1,208	18,652
B. NON ELIGIBLE PORTION				
a	Procurement / Construction	0	0	0
	Base cost for JICA financing	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
b	Land acquisition	0	0	0
	Base cost	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
c	Administration cost	0	173	145
d	VAT	2,822	193	2,984
e	Import tax	0	999	839
Total (a+b+c+d+e)		2,822	1,365	3,969
TOTAL (A+B)		20,459	2,573	22,621
C. Interest during Construction		1,003	0	1,003
	Interest during Construction(Const.)	1,002	0	1,002
	Interest during Construction (Consul.)	0	0	0
D. Commitment Charge		177	0	177
GRAND TOTAL (A+B+C+D)		21,639	2,573	23,800
E. Eligible Portion incl. IDC (A+C+D) for JICA Finance		18,817	1,208	19,831
F. of which, Ceiling Amount for JICA Finance		-	-	20,471

Source: Prepared by the Survey Team

Table 8-4 Project Cost at Scenario-A2 (General Untied Japanese ODA Loans)

Item		Total		
		FC	LC	Total
A. ELIGIBLE PORTION		Mil. Yen	Mil. PRs	Mil. Yen
I)	Procurement / Construction	17,015	1,029	17,879
	UNIT 1-4	14,403	714	15,003
	Base cost for JICA financing	14,403	714	15,003
	Price escalation	1,801	266	2,025
	Physical contingency	810	49	851
II)	Consulting services	1,094	230	1,287
	Base cost	930	161	1,065
	Price escalation	112	58	161
	Physical contingency	52	11	61
Total (I + II)		18,109	1,260	19,167
B. NON ELIGIBLE PORTION				
a	Procurement / Construction	0	0	0
	Base cost for JICA financing	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
b	Land acquisition	0	0	0
	Base cost	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
c	Administration cost	0	201	169
d	VAT	2,897	202	3,067
e	Import tax	0	1,013	851
Total (a+b+c+d+e)		2,897	1,415	4,086
TOTAL (A+B)		21,006	2,675	23,253
C. Interest during Construction		1,107	0	1,107
	Interest during Construction(Const.)	1,107	0	1,107
	Interest during Construction (Consul.)	1	0	1
D. Commitment Charge		203	0	203
GRAND TOTAL (A+B+C+D)		22,316	2,675	24,563
E. Eligible Portion incl. IDC (A+C+D) for JICA Finance		19,418	1,260	20,476
F. of which, Ceiling Amount for JICA Finance		-	-	20,878

Source: Prepared by the Survey Team

2) Scenario-B1 and B2

The estimated project implementation cost at Scenario-B1 and B2 under the condition of utilizing the general untied Japanese ODA loans is summarized in Tables 8-5 and 8-6 respectively.

Table 8-5 Project Cost at Scenario-B1 (General Untied Japanese ODA Loans)

Item		Total		
		FC	LC	Total
A. ELIGIBLE PORTION		Mil. Yen	Mil. PRs	Mil. Yen
I)	Procurement / Construction	28,347	1,705	29,779
	UNIT 1-6	24,072	1,194	25,075
	Base cost for JICA financing	24,072	1,194	25,075
	Price escalation	2,925	430	3,286
	Physical contingency	1,350	81	1,418
II)	Consulting services	1,162	352	1,458
	Base cost	997	250	1,207
	Price escalation	110	85	182
	Physical contingency	55	17	69
Total (I + II)		29,509	2,057	31,237
B. NON ELIGIBLE PORTION				
a	Procurement / Construction	0	0	0
	Base cost for JICA financing	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
b	Land acquisition	0	0	0
	Base cost	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
c	Administration cost	0	195	164
d	VAT	4,721	329	4,998
e	Import tax	0	1,687	1,417
Total (a+b+c+d+e)		4,721	2,211	6,579
TOTAL (A+B)		34,230	4,269	37,816
C. Interest during Construction		1,911	0	1,911
	Interest during Construction(Const.)	1,910	0	1,910
	Interest during Construction (Consul.)	1	0	1
D. Commitment Charge		331	0	331
GRAND TOTAL (A+B+C+D)		36,473	4,269	40,059
E. Eligible Portion incl. IDC (A+C+D) for JICA Finance		31,752	2,057	33,480
F. of which, Ceiling Amount for JICA Finance		-	-	34,050

Source: Prepared by the Survey Team

Table 8-6 Project Cost at Scenario-B2 (General Untied Japanese ODA Loans)

Item		Total		
		FC	LC	Total
A. ELIGIBLE PORTION		Mil. Yen	Mil. PRs	Mil. Yen
I)	Procurement / Construction	28,982	1,812	30,504
	UNIT 1-6	24,072	1,194	25,075
	Base cost for JICA financing	24,072	1,194	25,075
	Price escalation	3,530	531	3,977
	Physical contingency	1,380	86	1,453
II)	Consulting services	1,575	383	1,897
	Base cost	1,319	259	1,537
	Price escalation	181	106	270
	Physical contingency	75	18	90
Total (I + II)		30,557	2,195	32,401
B. NON ELIGIBLE PORTION				
a	Procurement / Construction	0	0	0
	Base cost for JICA financing	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
b	Land Acquisition	0	0	0
	Base cost	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
c	Administration cost	0	241	202
d	VAT	4,889	351	5,184
e	Import Tax	0	1,725	1,449
Total (a+b+c+d+e)		4,889	2,317	6,836
TOTAL (A+B)		35,446	4,512	39,236
C. Interest during Construction		2,379	0	2,379
	Interest during Construction(Const.)	2,377	0	2,377
	Interest during Construction (Consul.)	1	0	1
D. Commitment Charge		417	0	417
GRAND TOTAL (A+B+C+D)		38,242	4,512	42,032
E. Eligible Portion incl. IDC (A+C+D) for JICA Finance		33,353	2,195	35,196
F. of which, Ceiling Amount for JICA Finance		-	-	35,727

Source: Prepared by the Survey Team

(2) Climate Change Program Loan

1) Scenario-A1 and A2

In case of utilizing the Climate Change Program Loan which is applied an interest rate 0.3%, the estimated project costs at Scenario-A1 and A2 are summarized in Tables 8-7 and 8-8.

Table 8-7 Project Cost at Scenario-A1 (Climate Change Program Loan)

Item		Total		
		FC	LC	Total
A. ELIGIBLE PORTION		Mil. Yen	Mil. PRs	Mil. Yen
I)	Procurement / Construction	16,784	992	17,617
	UNIT 1-4	14,403	714	15,003
	Base cost for JICA financing	14,403	714	15,003
	Price escalation	1,582	230	1,775
	Physical contingency	799	47	839
II)	Consulting services	853	216	1,035
	Base cost	737	156	867
	Price escalation	76	50	118
	Physical contingency	41	10	49
Total (I + II)		17,637	1,208	18,652
B. NON ELIGIBLE PORTION				
a	Procurement / Construction	0	0	0
	Base cost for JICA financing	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
b	Land Acquisition	0	0	0
	Base cost	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
c	Administration cost	0	173	145
d	VAT	2,822	193	2,984
e	Import Tax	0	999	839
Total (a+b+c+d+e)		2,822	1,365	3,969
TOTAL (A+B)		20,459	2,573	22,621
C. Interest during Construction		211	0	211
	Interest during Construction(Const.)	211	0	211
	Interest during Construction (Consul.)	0	0	0
D. Commitment Charge		170	0	170
GRAND TOTAL (A+B+C+D)		20,840	2,573	23,002
E. Eligible Portion incl. IDC (A+C+D) for JICA Finance		18,018	1,208	19,033
F. of which, Ceiling Amount for JICA Finance		-	-	19,614

Source: Prepared by the Survey Team

Table 8-8 Project Cost at Scenario-A2 (Climate Change Program Loan)

Item		Total		
		FC	LC	Total
A. ELIGIBLE PORTION		Mil. Yen	Mil. PRs	Mil. Yen
I)	Procurement / Construction	17,015	1,029	17,879
	UNIT 1-4	14,403	714	15,003
	Base cost for JICA financing	14,403	714	15,003
	Price escalation	1,801	266	2,025
	Physical contingency	810	49	851
II)	Consulting services	1,094	230	1,287
	Base cost	930	161	1,065
	Price escalation	112	58	161
	Physical contingency	52	11	61
Total (I + II)		18,109	1,260	19,167
B. NON ELIGIBLE PORTION				
a	Procurement / Construction	0	0	0
	Base cost for JICA financing	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
b	Land Acquisition	0	0	0
	Base cost	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
c	Administration cost	0	201	169
d	VAT	2,897	202	3,067
e	Import Tax	0	1,013	851
Total (a+b+c+d+e)		2,897	1,415	4,086
TOTAL (A+B)		21,006	2,675	23,253
C. Interest during Construction		233	0	233
	Interest during Construction(Const.)	232	0	232
	Interest during Construction (Consul.)	1	0	1
D. Commitment Charge		194	0	194
GRAND TOTAL (A+B+C+D)		21,433	2,675	23,680
E. Eligible Portion incl. IDC (A+C+D) for JICA Finance		18,535	1,260	19,593
F. of which, Ceiling Amount for JICA Finance		-	-	20,128

Source: Prepared by the Survey Team

2) Scenario-B1 and B2

In case of utilizing the Climate Change Program Loan which is applied an interest rate 0.3%, the estimated project costs at Scenario-B1 and B2 are summarized in Tables 8-9 and 8-10.

Table 8-9 Project Cost at Scenario-B1 (Climate Change Program Loan)

Item		Total		
		FC	LC	Total
A. ELIGIBLE PORTION		Mil. Yen	Mil. PRs	Mil. Yen
I)	Procurement / Construction	28,347	1,705	29,779
	UNIT 1-6	24,072	1,194	25,075
	Base cost for JICA financing	24,072	1,194	25,075
	Price escalation	2,925	430	3,286
	Physical contingency	1,350	81	1,418
II)	Consulting services	1,162	352	1,458
	Base cost	997	250	1,207
	Price escalation	110	85	182
	Physical contingency	55	17	69
Total (I + II)		29,509	2,057	31,237
B. NON ELIGIBLE PORTION				
a	Procurement / Construction	0	0	0
	Base cost for JICA financing	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
b	Land Acquisition	0	0	0
	Base cost	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
c	Administration cost	0	195	164
d	VAT	4,721	329	4,998
e	Import Tax	0	1,687	1,417
Total (a+b+c+d+e)		4,721	2,211	6,579
TOTAL (A+B)		34,230	4,269	37,816
C. Interest during Construction		401	0	401
	Interest during Construction(Const.)	401	0	401
	Interest during Construction (Consul.)	1	0	1
D. Commitment Charge		316	0	316
GRAND TOTAL (A+B+C+D)		34,948	4,269	38,534
E. Eligible Portion incl. IDC (A+C+D) for JICA Finance		30,227	2,057	31,955
F. of which, Ceiling Amount for JICA Finance		-	-	32,754

Source: Prepared by the Survey Team

Table 8-10 Project Cost at Scenario-B2 (Climate Change Program Loan)

Item		Total		
		FC	LC	Total
A. ELIGIBLE PORTION		Mil. Yen	Mil. PRs	Mil. Yen
I)	Procurement / Construction	28,982	1,812	30,504
	UNIT 1-6	24,072	1,194	25,075
	Base cost for JICA financing	24,072	1,194	25,075
	Price escalation	3,530	531	3,977
	Physical contingency	1,380	86	1,453
II)	Consulting services	1,575	383	1,897
	Base cost	1,319	259	1,537
	Price escalation	181	106	270
	Physical contingency	75	18	90
Total (I + II)		30,557	2,195	32,401
B. NON ELIGIBLE PORTION				
a	Procurement / Construction	0	0	0
	Base cost for JICA financing	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
b	Land Acquisition	0	0	0
	Base cost	0	0	0
	Price escalation	0	0	0
	Physical contingency	0	0	0
c	Administration cost	0	241	202
d	VAT	4,889	351	5,184
e	Import Tax	0	1,725	1,449
Total (a+b+c+d+e)		4,889	2,317	6,836
TOTAL (A+B)		35,446	4,512	39,236
C. Interest during Construction		497	0	497
	Interest during Construction(Const.)	496	0	496
	Interest during Construction (Consul.)	1	0	1
D. Commitment Charge		395	0	395
GRAND TOTAL (A+B+C+D)		36,337	4,512	40,128
E. Eligible Portion incl. IDC (A+C+D) for JICA Finance		31,448	2,195	33,292
F. of which, Ceiling Amount for JICA Finance		-	-	34,109

Source: Prepared by the Survey Team

8.1.4 Project Cost Reduction Plan

(1) Assembling turbine and generator

There are two erection bays at both sides of Unit 1 and Unit 10 in powerhouse which have enough space for assembling turbine and generator at the same time.

Therefore, it is expected to shorten the construction schedule by use of two erection bays effectively.

(2) Centering method

By introducing the actual centering method at the installation of turbine and generator, it is expected to shorten the construction schedule as compared to the piano wire method which is a conventional method for installation of turbine and generator.

Actual centering method is to assemble from the lower parts to upper parts with setting and confirming the vertical center line on the assembled parts, and this method can eliminate tentative assembly of the parts such as upper bracket, guide vane and so on.

CHAPTER 9 FINANCIAL AND ECONOMIC ANALYSES

9.1 Objectives and Methodology

The financial and economic analyses aim to examine the viability of the project by calculating the internal rate of return (IRR) and the net present value (NPV).

9.1.1 Financial Analysis

Financial analysis is conducted to evaluate the profitability of the project from the viewpoint of the implementing organization. To obtain the financial internal rate of return (FIRR) and the financial net present value (FNPV), net benefit of the project is derived considering 1) the benefit (incremental revenue of bulk supply tariff) and 2) the cost based on the market price.

9.1.2 Economic Analysis

Economic analysis is conducted to evaluate the viability of the project from the viewpoint of the national economy. To obtain the economic internal rate of return (EIRR) and the economic net present value (ENPV), the benefit of the project is derived considering 1) the increased benefit based on the saved cost by replacing the alternative energy sources (e.g., diesel generators) and 2) the economic costs.

9.2 Conclusion of Financial and Economic Analyses

Based on the assumptions, costs and benefits calculated and described so far, the financial and economic IRRs and NPVs were calculated and presented in this section.

9.2.1 FIRR and FNPV

(1) Base Case

Benefit and cost were compiled and calculated considering the 2012 prices in order to obtain FIRR and were discounted using the opportunity cost of capital (12%) for attaining the FNPV.

Both Scenarios (Unit 1-4 and Unit 1-6) showed negative NPV and an FIRR which is lower than the cut-off rate. This is mainly caused by the assumption on the remaining life of the existing units as explained in the next section.

Table 9-1 FIRR and FNPV (Scenario A1)

Case	FIRR	FNPV (PRs million)	FNPV (US$ million)
Unit 1	5.9%	(2,292)	(24)
Unit 2	5.7%	(2,259)	(24)
Unit 3	5.6%	(2,192)	(23)

Unit 4	5.4%	(2,211)	(23)
Total	**5.7%**	**(8,954)**	**(95)**

Source: Prepared by the Survey Team

Table 9-2 FIRR and FNPV (Scenario A2)

Case	FIRR	FNPV (PRs million)	FNPV (US$ million)
Unit 1	5.8%	(2,320)	(25)
Unit 2	5.5%	(2,279)	(24)
Unit 3	5.2%	(2,233)	(24)
Unit 4	4.9%	(2,198)	(23)
Total	**5.4%**	**(9,030)**	**(96)**

Source: Prepared by the Survey Team

Table 9-3 FIRR and FNPV (Scenario B1)

Case	FIRR	FNPV (PRs million)	FNPV (US$ million)
Unit 1	5.5%	(2,294)	(24)
Unit 2	5.2%	(2,308)	(24)
Unit 3	5.2%	(2,241)	(24)
Unit 4	5.0%	(2,253)	(24)
Unit 5	4.2%	(3,295)	(35)
Unit 6	4.0%	(3,259)	(34)
Total	**4.8%**	**(15,651)**	**(166)**

Source: Prepared by the Survey Team

Table 9-4 FIRR and FNPV (Scenario B2)

Case	FIRR	FNPV (PRs million)	FNPV (US$ million)
Unit 1	5.1%	(2,308)	(24)
Unit 2	4.8%	(2,264)	(24)
Unit 3	4.5%	(2,218)	(23)
Unit 4	4.2%	(2,208)	(23)
Unit 5	4.1%	(3,357)	(36)
Unit 6	3.8%	(3,209)	(34)
Total	**4.4%**	**(15,565)**	**(165)**

Source: Prepared by the Survey Team

(2) Sensitivity Analysis

Sensitivity analysis was conducted for the financial analysis as the actual condition may be different from those assumed for the base case. In the sensitivity analysis, 1) tariff increase (10%), 2) cost increase (10%), 3) delay in construction (1 year), 4) shorter life of existing units (45 years), and 5) CDM benefit were considered.

Table 9-5 Sensitivity Analysis for Scenario A1 (FIRR & FNPV)

Case	Benefit	Cost	FIRR (%)	FNPV (Mil PRs)	FNPV (Mil US$)
Base case	No change	No change	5.7%	(8,954)	(95)
Tariff increase (+10%)	+10%	No change	6.5%	(8,256)	(87)
Cost increase (+10%)	No change	+10%	5.0%	(10,347)	(109)
Delay in construction (1 yr)	No change	No change	5.5%	(8,564)	(91)
Shorter life of existing unit (45 yrs)	No change	No change	9.2%	(2,745)	(29)
With CDM benefit	+CDM benefit	No change	8.2%	(5,591)	(58)

Source: Prepared by the Survey Team

Table 9-6 Sensitivity Analysis for Scenario A2 (FIRR & FNPV)

Case	Benefit	Cost	FIRR (%)	FNPV (Mil PRs)	(Mil US$)
Base case	No change	No change	5.4%	(9,030)	(96)
Tariff increase (+10%)	+10%	No change	6.2%	(8,416)	(89)
Cost increase (+10%)	No change	+10%	4.7%	(10,357)	(110)
Delay in construction (1 yr)	No change	No change	5.1%	(8,778)	(93)
Shorter life of existing unit (45 yrs)	No change	No change	8.9%	(2,821)	(30)
With CDM benefit	+CDM benefit	No change	7.8%	(6,038)	(63)

Source: Prepared by the Survey Team

Table 9-7 Sensitivity Analysis for Scenario B1 (FIRR & FNPV)

Case	Benefit	Cost	FIRR (%)	FNPV (Mil PRs)	(Mil US$)
Base case	No change	No change	4.8%	(15,651)	(166)
Tariff increase (+10%)	+10%	No change	5.6%	(14,712)	(156)
Cost increase (+10%)	No change	+10%	4.1%	(17,869)	(189)
Delay in construction (1 yr)	No change	No change	4.5%	(15,046)	(159)
Shorter life of existing unit (45 yrs)	No change	No change	7.8%	(6,337)	(67)
With CDM benefit	+CDM benefit	No change	7.2%	(10,597)	(112)

Source: Prepared by the Survey Team

Table 9-8 Sensitivity Analysis for Scenario B2 (FIRR & FNPV)

Case	Benefit	Cost	FIRR (%)	FNPV (Mil PRs)	(Mil US$)
Base case	No change	No change	4.4%	(15,565)	(165)
Tariff increase (+10%)	+10%	No change	5.2%	(14,822)	(157)
Cost increase (+10%)	No change	+10%	3.7%	(17,603)	(186)
Delay in construction (1 yr)	No change	No change	4.1%	(14,969)	(158)
Shorter life of existing unit (45 yrs)	No change	No change	7.5%	(6,251)	(66)
With CDM benefit	+CDM benefit	No change	6.6%	(11,566)	(120)

Source: Prepared by the Survey Team

It is clear from the figures above that the change in the level of benefit and cost and the delay in construction did not significantly change the IRR (less than 1%).

On the contrary, the impact of the change in the assumption on the remaining life of the existing units was evident and more significant than the change in the level of benefit and cost and the delay in construction.

The reason for this can be explained from the formula of calculating net incremental benefit. As explained in the previous section, the generation and tariff revenues of the existing units during the construction and installation period are recognized as forgone benefits when they are forced to stop operation. If the remaining life of the existing units is assumed to be shorter, the foregone benefit will become smaller accordingly.

Additional CDM benefit can increase the IRR by more than 1%. However, as mentioned earlier, there is uncertainty that the Project is eligible for this benefit at this stage.

9.2.2 EIRR and ENPV

(1) Base Case

The benefit and cost were compiled and calculated using the economic cost, in order to obtain EIRR and were discounted using the social discount rate (12%) for attaining the ENPV.

In contrast with the FIRR, EIRR was higher than the cut-off rate in the base case of all cases. This difference is explained by the huge gap between 1) the level of the economic benefit (i.e., PRs 15.67/kWh) in economic analysis and 2) the incremental tariff revenue in financial analysis.

Table 9-9 EIRR and ENPV (Scenario A1)

Case	EIRR (%)	ENPV (PRs million)	ENPV (US$ million)
Unit 1	20.7%	18,246	193
Unit 2	19.3%	15,781	167
Unit 3	18.6%	14,424	153
Unit 4	17.4%	12,185	129
Total	**19.0%**	**60,636**	**642**

Source: Prepared by the Survey Team

Table 9-10 EIRR and ENPV (Scenario A2)

Case	EIRR (%)	ENPV (PRs million)	ENPV (US$ million)
Unit 1	20.7%	18,231	193
Unit 2	18.6%	14,543	154
Unit 3	17.0%	11,342	120
Unit 4	15.6%	8,380	89
Total	**17.9%**	**52,496**	**556**

Source: Prepared by the Survey Team

Table 9-11 EIRR and ENPV (Scenario B1)

Case	EIRR (%)	ENPV (PRs million)	ENPV (US$ million)
Unit 1	18.5%	14,397	152
Unit 2	17.4%	12,159	129
Unit 3	16.8%	10,950	116
Unit 4	15.8%	8,951	95
Unit 5	20.1%	17,305	183
Unit 6	18.7%	14,853	157
Total	**17.9%**	**78,615**	**832**

Source: Prepared by the Survey Team

Table 9-12 EIRR and ENPV (Scenario B2)

Case	EIRR (%)	ENPV (PRs million)	ENPV (US$ million)
Unit 1	17.0%	11,335	120
Unit 2	15.6%	8,375	89
Unit 3	14.4%	5,781	61
Unit 4	13.4%	3,381	36
Unit 5	20.1%	17,269	183
Unit 6	18.1%	13,680	145
Total	**16.4%**	**59,821**	**633**

Source: Prepared by the Survey Team

ENPV of each unit showed positive benefit. While the FNPV of both scenarios showed deficit, it can be concluded that the economic benefit of the Project is robust as the people in Pakistan are paying very high costs for alternative energy sources (i.e. diesel generators and UPS) due to insufficient supply of electricity and the Project can be justified from the viewpoint of the national economy.

(2) Sensitivity Analysis

The sensitivity analysis was conducted for economic analysis. Similar to the financial analysis, increase in economic benefit, cost overrun of construction, delay in construction, change in the assumption of the remaining life of the existing units, and CDM benefit were considered.

The results of sensitive analysis for EIRR and ENPV were similar to those of FIRR and FNPV. The impact on EIRR and ENPV of the change in the level of benefit and cost was relatively small. Delay in construction increased the figures of EIRR and ENPV slightly. The change in the assumption on the remaining life of the existing units drastically increased the figures of EIRR and ENPV. Unlike financial analysis, the impact of additional CDM benefit is limited as it is small compared with the huge economic benefit (saving of the cost for alternative energy source).

Table 9-13 Sensitivity Analysis for Scenario A1 (EIRR & ENPV)

Case	Benefit	Cost	EIRR (%)	ENPV (PRs million)	ENPV (US$ million)
Base case	No change	No change	19.0%	60,636	642
Benefit increase (+10%)	+10%	No change	19.1%	67,882	718
Cost increase (+10%)	No change	+10%	18.8%	59,487	629
Delay in construction (1 yr)	No change	No change	19.3%	62,066	657
Shorter life of existing unit (45 yrs)	No change	No change	80.7%	125,070	1,323
With CDM benefit	+CDM benefit	No change	19.2%	63,260	669

Source: Prepared by the Survey Team

Table 9-14 Sensitivity Analysis for Scenario A2 (EIRR & ENPV)

Case	Benefit	Cost	EIRR (%)	ENPV (PRs million)	ENPV (US$ million)
Base case	No change	No change	17.9%	52,496	556
Benefit increase (+10%)	+10%	No change	18.1%	58,873	623
Cost increase (+10%)	No change	+10%	17.8%	51,404	544
Delay in construction (1 yr)	No change	No change	18.2%	53,935	571
Shorter life of existing unit (45 yrs)	No change	No change	80.3%	116,931	1,237
With CDM benefit	+CDM benefit	No change	18.1%	54,830	580

Source: Prepared by the Survey Team

Table 9-15 Sensitivity Analysis for Scenario B1 (EIRR & ENPV)

Case	Benefit	Cost	EIRR (%)	ENPV (PRs million)	ENPV (US$ million)
Base case	No change	No change	17.9%	78,615	832
Benefit increase (+10%)	+10%	No change	18.0%	88,356	935
Cost increase (+10%)	No change	+10%	17.7%	76,783	813
Delay in construction (1 yr)	No change	No change	18.1%	80,825	855
Shorter life of existing unit (45 yrs)	No change	No change	72.8%	175,266	1,855
With CDM benefit	+CDM benefit	No change	18.1%	82,557	874

Source: Prepared by the Survey Team

Table 9-16 Sensitivity Analysis for Scenario B2 (EIRR & ENPV)

Case	Benefit	Cost	EIRR (%)	ENPV (PRs million)	ENPV (US$ million)
Base case	No change	No change	16.4%	59,821	633
Benefit increase (+10%)	+10%	No change	16.5%	67,532	715
Cost increase (+10%)	No change	+10%	16.2%	58,139	615
Delay in construction (1 yr)	No change	No change	16.6%	61,888	655
Shorter life of existing unit (45 yrs)	No change	No change	71.5%	156,472	1,656
With CDM benefit	+CDM benefit	No change	16.6%	62,940	666

Source: Prepared by the Survey Team

9.3 Operation and Effect Indicators

Envisaged operation and effect indicators of the Project are as follows:

1) Operation indicators
   - Maximum output of Mangla Power Station [MW]
   - Average annual power generation of Mangla Power Station [GWh]
   - Average plant factor of Mangla Power Station [%]
2) Effect indicators
   - Increase in the earnings of WAPDA
   - Contribution to the reduction of carbon dioxide by decreasing the usage of kerosene and diesel oil etc.

Table 9-51 shows operation and effect indicators to measure the quantitative effects of the Project including target values at the time after completion of the Project.

Table 9-17 Operation and Effect Indicators

<table>
<tr><th rowspan="2">Indicators</th><th rowspan="2">Present Conditions
in 2012</th><th colspan="2">Target</th></tr>
<tr><th>Scenario-A
(for 4 units)
The target year is 2021</th><th>Scenario-B
(for 6 units)
The target year is 2023</th></tr>
<tr><td>Maximum output</td><td>1,150 [MW]</td><td>1,230 [MW]</td><td>1,270 [MW]</td></tr>
<tr><td rowspan="2">Average annual power generation</td><td>2,753[GWh]
(for 4 units)</td><td>3,232 [GWh]</td><td>-</td></tr>
<tr><td>4,130[GWh]
(for 6 units)</td><td>-</td><td>4,848 [GWh]</td></tr>
<tr><td>Average plant factor</td><td>49.6 [%]</td><td>60.6 [%]</td><td>59.2 [%]</td></tr>
<tr><td rowspan="2">Increase in the earnings of WAPDA</td><td>3,242
[PRs Mil/year]
(for 4 units)</td><td>3,807
[PRs Mil/year]</td><td>-</td></tr>
<tr><td>4,864
[PRs Mil/year]
(for 6 units)</td><td>-</td><td>5,710
[PRs Mil/year]</td></tr>
<tr><td>Contribution to the reduction of carbon dioxide</td><td>-</td><td>1,334,527
[t-CO2/year]</td><td>1,383,118
[t-CO2/year]</td></tr>
</table>

Note: The figures of power generation and earnings are based on those of financial analysis.
Source: Prepared by the Survey Team

CHAPTER 10 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

10.1.1 Project Outline

The project outline based on the recommendation of enhancement of generator's output up to 135 MW is as below.

1) Rehabilitation and Enhancement

The scenarios for rehabilitation and enhancement project of Mangla Power Station with enhanced generator's output 135 MW are summarized in Table 10-1.

Table 10-1 Recommended Scenarios

Scenarios	Subject Unit	No. of Units of Stoppage	Project Cost		Economic IRR	Financial IRR
			General Untied Japanese ODA	Climate Change Program		
Scenario-A1	Units 1-4 (4 units)	Double units	USD 294.2 mil. (JPY 23,800 mil.)	USD 284.3 mil. (JPY 23,002 mil.)	19.0 %	5.7 %
Scenario-A2		Single unit	USD 303.6 mil. (JPY 24,563 mil.)	USD 292.7 mil. (JPY 23,680 mil.)	17.9 %	5.4 %
Scenario-B1	Units 1-6 (6 units)	Double units	USD 495.2 mil. (JPY 40,059 mil.)	USD 476.3 mil. (JPY 38,534 mil.)	17.9 %	4.8 %
Scenario-B2		Single unit	USD 519.6 mil. (JPY 42,032 mil.)	USD 496.0 mil. (JPY 40,128 mil.)	16.4 %	4.4 %

Source: Prepared by the Survey Team USD 1= JPY 80.9

2) Implementation Period of the Project

The implementation period of the Project from the signing of the Loan Agreement (L/A) up to completion of the Project at all scenarios is shown in Table 10-2.

Table 10-2 Project Implementation Period

Stage	Scenarios				Remarks
	Scenario-A1	Scenario-A2	Scenario-B1	Scenario-B2	
Pre-construction Stage	30 months	30 months	30 months	30 months	Procurement of Consultant, Preparation of Tender Documents and Tendering Stage
Construction Stage	65 months	80 months	77 months	102 months	Rehabilitation and Enhancement Works
Total	95 months	110 months	107 months	132 months	-

Source: Prepared by the Survey Team

3) Project Cost

3)-1. General Untied Japanese ODA Loans

i) Scenario-A1 and A2

The estimated project cost at Scenario-A1 and A2 under the condition of utilizing the general untied Japanese ODA loans is summarized in Table 10-3.

Table 10-3 Project Cost at Scenario-A1 and A2

-	Scenario-A1			Scenario-A2		
	FC	LC	Total	FC	LC	Total
1. Construction Cost	USD 207.5 mil. (JPY 16,784 mil.)	USD 10.3 mil. (JPY 833 mil.)	USD 217.8 mil. (JPY 17,617 mil.)	USD 210.3 mil. (JPY 17,015 mil.)	USD 10.7 mil. (JPY 864 mil.)	USD 221.0 mil. (JPY 17,879 mil.)
2. Consulting Services Cost	USD 10.5 mil. (JPY 853 mil.)	USD 2.2 mil. (JPY 182 mil.)	USD 12.8 mil. (JPY 1,035 mil.)	USD 13.5 mil. (JPY 1,094 mil.)	USD 2.4 mil. (JPY 193 mil.)	USD 15.9 mil. (JPY 1,287 mil.)
3. Interest during Construction, Commitment Charge	USD 14.6 mil. (JPY 1,180 mil.)	0	USD 14.6 mil. (JPY 1,180 mil.)	USD 16.2 mil. (JPY 1,310 mil.)	0	USD 16.2 mil. (JPY 1,310 mil.)
4. Others (Administration Cost, VAT, Import Tax)	USD 34.9 mil. (JPY 2,822 mil.)	USD 14.2 mil. (JPY 1,147 mil.)	USD 49.1 mil. (JPY 3,969 mil.)	USD 35.8 mil. (JPY 2,897 mil.)	USD 14.7 mil. (JPY 1,189 mil.)	USD 50.5 mil. (JPY 4,086 mil.)
Total Cost	**USD 267.5 mil. (JPY 21,639 mil.)**	**USD 26.7 mil. (JPY 2,161 mil.)**	**USD 294.2 mil. (JPY 23,800 mil.)**	**USD 275.8 mil. (JPY 22,316 mil.)**	**USD 27.8 mil. (JPY 2,247 mil.)**	**USD 303.6 mil. (JPY 24,563 mil.)**

USD 1= JPY 80.9

Note: 1) Items No. 1, 2 and 3 shall be borne by JICA Finance.
2) Item No. 4 shall be borne by WAPDA or the Government of Pakistan depending upon approval by the Planning Commission of Pakistan.

Source: Prepared by the Survey Team

ii) Scenario-B1 and B2

The estimated project cost at Scenarios-B1 and B2 under the condition of utilizing the general untied Japanese ODA loans is summarized in Table 10-4.

Table 10-4 Project Cost at Scenario-B1 and B2

-	Scenario-B1			Scenario-B2		
	FC	LC	Total	FC	LC	Total
1. Construction Cost	USD 350,4 mil. (JPY 28,347 mil.)	USD 17.7 mil. (JPY 1,432 mil.)	USD 368.1 mil. (JPY 29,779 mil.)	USD 358.2 mil. (JPY 28,982 mil.)	USD 18.8 mil. (JPY 1,522 mil.)	USD 377.1 mil. (JPY 30,504 mil.)
2. Consulting Services Cost	USD 14.4 mil. (JPY 1,162 mil.)	USD 3.7 mil. (JPY 296 mil.)	USD 18.0 mil. (JPY 1,458 mil.)	USD 19.5 mil. (JPY 1,575 mil.)	USD 4.0 mil. (JPY 322 mil.)	USD 23.4 mil. (JPY 1,897 mil.)
3. Interest during Construction, Commitment Charge	USD 27.7 mil. (JPY 2,242 mil.)	0	USD 27.7 mil. (JPY 2,242 mil.)	USD 34.6 mil. (JPY 2,796 mil.)	0	USD 34.6 mil. (JPY 2,796 mil.)
4. Others (Administration Cost, VAT, Import Tax)	USD 58.4 mil. (JPY 4,721 mil.)	USD 23.0 mil. (JPY 1,858 mil.)	USD 81.3 mil. (JPY 6,579 mil.)	USD 60.4 mil. (JPY 4,889 mil.)	USD 24.1 mil. (JPY 1,947 mil.)	USD 84.5 mil. (JPY 6,836 mil.)
Total Cost	**USD 450.8 mil. (JPY 36,473 mil.)**	**USD 44.3 mil. (JPY 3,586 mil.)**	**USD 495.2 mil. (JPY 40,059 mil.)**	**USD 472.7 mil. (JPY 38,242 mil.)**	**USD 46.8 mil. (JPY 3,790 mil.)**	**USD 519.6 mil. (JPY 42,032 mil.)**

USD 1= JPY 80.9

Note: 1) Items No. 1, 2 and 3 shall be borne by JICA Finance.
2) Item No. 4 shall be borne by WAPDA or the Government of Pakistan depending upon approval by the Planning Commission of Pakistan.

Source: Prepared by the Survey Team

4)-2. Climate Change Program Loan

i) Scenario-A1 and A2

The estimated project cost at Scenario-A1 and A2 under the condition of utilizing the climate change program loan is summarized in Table 10-5.

Table 10-5 Project Cost at Scenario-A1 and A2

-	Scenario-A1			Scenario-A2		
	FC	LC	Total	FC	LC	Total
1. Construction Cost	USD 207.5 mil. (JPY 16,784 mil.)	USD 10.3 mil. (JPY 833 mil.)	USD 217.8 mil. (JPY 17,617 mil.)	USD 210.3 mil. (JPY 17,015 mil.)	USD 10.7 mil. (JPY 864 mil.)	USD 221.0 mil. (JPY 17,879 mil.)
2. Consulting Services Cost	USD 10.5 mil. (JPY 853 mil.)	USD 2.2 mil. (JPY 182 mil.)	USD 12.8 mil. (JPY 1,035 mil.)	USD 13.5 mil. (JPY 1,094 mil.)	USD 2.4 mil. (JPY 193 mil.)	USD 15.9 mil. (JPY 1,287 mil.)
3. Interest during Construction, Commitment Charge	USD 4.7 mil. (JPY 381 mil.)	0	USD 4.7 mil. (JPY 381 mil.)	USD 5.3 mil. (JPY 427 mil.)	0	USD 5.3 mil. (JPY 427 mil.)
4. Others (Administration Cost, VAT, Import Tax)	USD 34.9 mil. (JPY 2,822 mil.)	USD 14.2 mil. (JPY 1,147 mil.)	USD 49.1 mil. (JPY 3,969 mil.)	USD 35.8 mil. (JPY 2,897 mil.)	USD 14.7 mil. (JPY 1,189 mil.)	USD 50.5 mil. (JPY 4,086 mil.)
Total Cost	**USD 257.6 mil. (JPY 20,840 mil.)**	**USD 26.7 mil. (JPY 2,162 mil.)**	**USD 284.3 mil. (JPY 23,002 mil.)**	**USD 264.9 mil. (JPY 21,433 mil.)**	**USD 27.8 mil. (JPY 2,247 mil.)**	**USD 292.7 mil. (JPY 23,680 mil.)**

USD 1= JPY 80.9

Note: 1) Items No. 1, 2 and 3 shall be borne by JICA Finance.
2) Item No. 4 shall be borne by WAPDA or the Government of Pakistan depending upon approval by the Planning Commission of Pakistan.
Source: Prepared by the Survey Team

ii) Scenario-B1 and B2

The estimated project cost at Scenario-B1 and B2 under the condition of utilizing the climate change program loan is summarized in Table 10-6.

Table 10-6 Project Cost at Scenario-B1 and B2

-	Scenario-B1			Scenario-B2		
	FC	LC	Total	FC	LC	Total
1. Construction Cost	USD 350.4 mil. (JPY 28,347 mil.)	USD 17.9 mil. (JPY 1,452 mil.)	USD 368.3 mil. (JPY 29,799 mil.)	USD 358.2 mil. (JPY 28,982 mil.)	USD 18.8 mil. (JPY 1,522 mil.)	USD 377.1 mil. (JPY 30,504 mil.)
2. Consulting Services Cost	USD 14.4 mil. (JPY 1,162 mil.)	USD 3.7 mil. (JPY 296 mil.)	USD 18.0 mil. (JPY 1,458 mil.)	USD 19.5 mil. (JPY 1,575 mil.)	USD 4.0 mil. (JPY 322 mil.)	USD 23.4 mil. (JPY 1,897 mil.)
3. Interest during Construction, Commitment Charge	USD 8.9 mil. (JPY 717 mil.)	0	USD 8.9 mil. (JPY 717 mil.)	USD 11.0 mil. (JPY 892 mil.)	0	USD 11.0 mil. (JPY 892 mil.)
4. Others (Administration Cost, VAT, Import Tax)	USD 58.4 mil. (JPY 4,721 mil.)	USD 23.0 mil. (JPY 1,858 mil.)	USD 81.3 mil. (JPY 6,579 mil.)	USD 60.4 mil. (JPY 4,889 mil.)	USD 24.1 mil. (JPY 1,947 mil.)	USD 84.5 mil. (JPY 6,836 mil.)
Total Cost	**USD 432.0 mil. (JPY 34,948 mil.)**	**USD 44.3 mil. (JPY 3,586 mil.)**	**USD 476.3 mil. (JPY 38,534 mil.)**	**USD 449.2 mil. (JPY 36,337 mil.)**	**USD 46.9 mil. (JPY 3,791 mil.)**	**USD 496.0 mil. (JPY 40,128 mil.)**

USD 1= JPY 80.9

Note: 1) Items No. 1, 2 and 3 shall be borne by JICA Finance.
2) Item No. 4 shall be borne by WAPDA or the Government of Pakistan depending upon approval by the Planning Commission of Pakistan
Source: Prepared by the Survey Team

10.2 Recommendations Prior to Implementation

As previously stated, after the conclusion of the L/A, it will take at least 30 months to secure a contract with a contractor for the rehabilitation and enhancement works. The recommendations for maintenance are to be done by the implementation agency prior to the implementation of the Project as stated below:

- To clean up erection bays;
- To confirm the operating conditions of the lifting beam, lifting device, and wire;
- To confirm the operating conditions of overhead traveling crane with inching operation; and
- To clean up the inside of water pits and generator rooms.

10.3 Recommendations for Monitoring System Using Japanese Technology

The sedimentation of Mangla Dam is being surveyed every three to five years since the 1970's and its volume is shown in Table 4-25. The annual average sedimentation is 36.13 million m^3. If the situation of sedimentation and its volume are observed in an earlier time, the appropriate counter measures against sedimentation may be considered and implemented for each river properly. Therefore, the reservoir will be effectively used for irrigation/hydraulic power after preventing sedimentation. In the past, the survey of sedimentation took more than two months. If the survey is conducted using GPS and multi-beam sonar sounding system by Japanese technology, the period of survey would be shortened and accurate sedimentation volume would be obtained.

On the other hand, the movement monitoring system is being conducted at the power house but the existing equipment are old model and manually operated. The updated model shall be recommended for installation to obtain accurate monitoring. The updated equipment is very accurate and the data is transmitted by wireless to the centralized monitor station, which is useful during emergency period. Using the updated monitoring system, the movement of the dam body and power station and pore-water pressure shall be observed at the centralized monitor station in real time to prevent accidents.