are described in Sub-section 7.1.2.

4.7 Study on Selection of Combined Cycle Power Plant

4.7.1 Fuel Flexibility of Combined Cycle Power Plant

Generally CCPP is planned to utilize gas as fuel, however there are many CCPPs with diesel oil back up system considering emergency purpose in case of gas supply shut down. The Project has planned to utilize natural gas produced in Bangladesh as fuel however alternative fuel has to be evaluated because gas shortage is expected as described in Section 4.5.
Table I-4-7-1 shows the unit price of fuel as of summer 2007. Local gas price is extremely cheaper than international price. Comparing the price ratio of heavy oil and diesel oil, heavy oil price in Bangladesh is regulated around a half of diesel oil price. Therefore the feasibility of gas / heavy oil (HO)-fired CCPP is evaluated at first and next the feasibility of gas / diesel oil (DO)-fired oil CCPP is evaluated.

Table I-4-7-1 Unit price of fuel as of Summer 2007

	International	In Bangladesh
Gas / $/GJ	7.5	0.98
Heavy Oil / $/GJ	11.0	6.4
Diesel Oil / $/GJ	16.1	12.4

(1) Evaluation of gas / heavy oil-fired CCPP

1) Technical evaluation of heavy oil-fired CCPP

a. Supply record for a heavy oil-fired gas turbine

Whether heavy oil can be burnt in a gas turbine (GT) or not should be evaluated in terms of turbine inlet temperature, cooling structure of the hot gas parts, heavy oil properties, and experience with the heavy-oil burning in the gas turbine. The combustion temperature (defined in terms of the turbine inlet temperature) of the field-proven heavy oil-fired turbine gas turbine is up to about 1,050 °C i.e. the type of such gas turbine is E class. The heavy oil-fired gas turbine has been developed in the 1950s and has been put into commercial operation. However, as is discussed in detail in Section B, its development and operation are accompanied by many technical problems such as corrosion by heavy metal in heavy oil and deterioration in performance by deposition of ash. Thus, this type of turbine is hardly used in currently operating power plants. The Table I-4-7-2 shows the field-proven heavy oil-fired gas turbines of the scale conforming to the target of this project which have been extracted from the gas turbine delivery list of Alstom, GE and Mitsubishi Heavy Industries as the major gas turbine manufacturers. From the delivery list of Siemens, it was not possible to extract heavy oil-fired gas turbines; therefore Siemens' products are not included in the table.

Table I-4-7-2 Typical contract record of a heavy oil-fired gas turbine

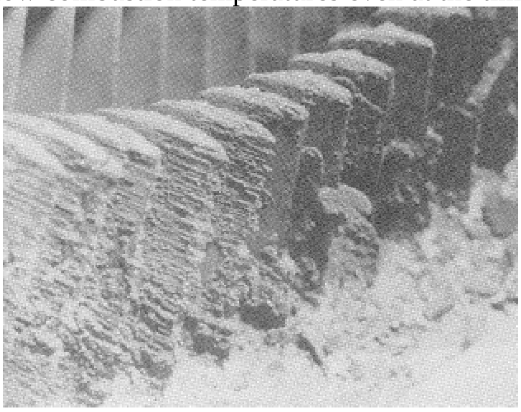
GT manufacturer	Plant Name	Country	Plant Output / MW	Number of GTs	GT model
Alstom	Foshan	China	280	2	GT13D
	Timelkam	Austria	107	1	GT13D
GE	Baochang 1	China	-	1	MS9001E
	Nanshan	China	-	4	MS9001E
	Yueliangwan	China	-	1	MS9001E
	Zhenhai	China	-	2	MS9001E

As shown above, eleven heavy oil-fired gas turbines of classes D and E have been delivered. Ten of them are operating in China.
The following shows our technical and economic evaluation having been conducted based on the results from surveying the Nanshan Power Plant as a heavy oil-fired CCPP of the world's greatest scale.

b. Technical issues

a) Gas turbine

When heavy oil is burnt in a gas turbine, the low-melting point compound (The lowest temperature is around 500 to 600°C.) of the vanadium, sodium, and sulfur as trace components contained in the heavy oil is deposited on the surface of the hot gas parts such as a turbine blade. This will cause corrosion of the base material of the hot gas parts, and will plug the cooling hole of those. Figure I-4-7-1 shows an example of ash deposited on the turbine blade. As illustrated, since much ash is deposited, some manufacturers are not willing to adopt heavy oil-firing depending on the cooling structure of hot gas parts.
The dual fuel of heavy oil and gas (to be switched for use) can be used if the combustion temperature is not raised at the time of gas-firing. If the combustion temperature is raised at the time of gas-firing, corrosivity of the compound deposited on the surface of the hot gas parts when the heavy oil is burnt is activated. Accordingly, operation may be possible only at a low combustion temperatures even at the time of gas-firing as well.



(source) Journal of the Japan Society of Gas Turbine, Vol. 36, No. 3

Figure I-4-7-1 An example of ash deposited on the 1st stage nozzle of a turbine

The properties of the fuel oil that can be used in the gas turbine are stipulated in ISO 4261. According to this provision, the limit value of 0.5 ppm (mass) is stipulated for vanadium, sodium + potassium, calcium, and lead. Except for calcium, a similar value is set in Mitsubishi Heavy Industries, GE, Alstom, and Siemens. Thus, if the oil fuel exceeds the said limit value, it must be subjected to some pre-treatment.
The "sodium + potassium" is normally mixed in the oil in solution in water. There are two methods of separation -- a method where water is added to oil (about 10 to 15%), and separation is made by a centrifugal separator using the difference in specific gravity; and a method where electric charge is applied to droplets dissolved sodium therein so that greater droplets are produced, and separation is made by free fall using the difference in specific gravity.
At present, there is no commercial facility which is capable to pre-treat the components other than "sodium + potassium". There is a method where the magnesium compound (magnesium hydroxide, magnesium sulfide, etc.) in the amount of three times that of vanadium is added to the fuel oil. It is also possible to add a silica compound to rise in the melting point of the combusted compound and to be flyable.

Based on the aforementioned discussion, heavy oil-fired gas turbines require the following measures to be taken in order to prevent the said troubles:

a. Fuel purification: cleaning and additive
b. Reduction in combustion temperatures
c. Periodic cleaning of the turbine blade

b) Heat Recovery Steam Generator (HRSG)
Similarly to the case of the gas turbine, the following measures must be taken by giving consideration to adverse effects resulting from deposition of ash, plugging, and corrosive components.
a. Installation of a soot blower to prevent performance loss by deposition of ash on the boiler tube and fin
b. Rise the feed water temperature to prevent corrosion of the economizer when sulfur contents are included

c. Plant performance
The Nanshan power plant includes four CCPP using the GE's E class gas turbines (PG9171E). Table I-4-7-3 shows their average performances. In case of heavy oil fired, since the combustion temperature is reduced by about 30 °C for operation to avoid high temperature corrosion, gas turbine output is reduced by about 17% and plant efficiency is reduced by about 16%. In other words, the plant efficiency of the heavy oil-fired CCPP is reduced to the level of the conventional thermal power plant. This means a loss of "efficiency" which is the greatest advantage of the CCPP.

Table I-4-7-3 Plant performance of heavy oil-fired CCPP

	Gas	Heavy Oil
GT Output / MW	120	100
CCPP Efficiency / %	52	45

d. Plant operability
The heavy oil-fired CCPP require periodic cleaning and inspection of the turbine blade. Plant shutdown must be implemented frequently as described below:

a) Blade cleaning
Plant shutdown of 12 hours is required for each cumulative 80-hour operation.

b) Bore scope inspection
Plant shutdown of 2 hours is required for each cumulative 800-hour operation.

c) Inspection of hot gas parts
The inspection of the hot gas parts is required every 24,000 hours at the time of gas-fired operation but should be performed every 15,000 to 18,000 hours at the time of oil-fired operation.

Based on the aforementioned plant shutdown time, the annual average availability is calculated as follows:

Operation time: 800 hours/cycle* = 6,740 hours/year

Shutdown time for blade cleaning:	108 hours/cycle* = 900 hours/year
Shutdown time for bore scope inspection:	48 hours/cycle* = 400 hours/year
Work shutdown time:	360 hours/year
Shutdown time for accidents:	360 hours/year
Annual average availability:	6740/8760 = 76.9%

* One cycle is defined as the inspection shutdown time for each borescope.

Thus, the availability is reduced by about 15% per year due to shutdown for blade cleaning and bore scope inspection. As compared to the annual average availability of about 92% in case of the gas-fired CCPP, the availability in the heavy oil-fired CCPP is estimated at 77%. This figure is a considerably low figure.
The Bheramara CCPP is ranked as an important base load plant in the western part of Bangladesh. Therefore the heavy oil-fired CCPP showing such a low availability is not appropriate option for the Bheramara CCPP.

2) Economical Evaluation

As economical evaluation of the heavy oil-fired CCPP, we compare the estimated the fuel cost of the heavy oil-fired CCPP with that of the conventional thermal power plant. The unit fuel price in Table I-4-7-1 is used and Table I-4-7-4 shows the conditions for cost estimation. The performance of the heavy oil-fired CCPP in Tables I-4-7-3 includes the consideration of the said reduction in performance and availability. Further, as shown in Tables I-4-7-4, the unit price of each fuel in Bangladesh is far different from the international price level. This has a serious impact on the results of this evaluation.

Table I-4-7-4 Basic conditions for fuel cost evaluation

		Gas/HO CCPP	Gas/HO Conventional PP
Output / MW	Gas	360	360
	Oil	300	360
Operating Hour / hrs/yr	Gas	8000	8000
	Oil	6700	8000
Heat Rate / %(LHV)	Gas	52%	Gas: 45%
	Oil	45%	HO: 45%

At the time of 100% gas-fired operation, the thermal efficiency of the CCPP is higher than that of the conventional thermal power plant. Accordingly, the annual fuel cost of the CCPP is much more advantageous. However, when the heavy oil-fired operation is taken into account, the conventional thermal power plant can be economical depending on certain conditions due to the influence of the unit prices of gas and oil.
Table I-4-7-5 shows an example of estimation of the annual fuel cost per annual power generation of 2.9 TWh (= 360 MW x 8000 hours) in each power generation facility. In this estimation of the gas/heavy oil-fired CCPP, the amount of power generation corresponding to the output derating and outage is assumed to be backed up by other power plant in grid. As shown in the following table, it has been concluded that the gas/heavy oil-fired CCPP are less economical than a conventional thermal power plant even in case fuel oil is used 10%.

Table I-4-7-5 Result of tentative calculation of the fuel cost in power generation facilities

		Hourly Fuel Cost ($/hr)	Operating Hour (hrs)	Annual Fuel Cost (mil. USD)
Gas/HO dual CCPP	Gas	2442	7200	17.6
	HO	15461	670	10.4
	Back up due to output derating	9055	670	6.1
	Back up due to outage	54331	130	7.1
	Total			41.1
Conventional TPP	Gas	2822	7200	20.3
	HO	18554	800	14.8
	Total			35.2

Estimate conditions: Gas/heavy oil ratio = 90%/10%, Fuel cost: local price in Bangladesh

The above estimation is based on the local fuel price in Bangladesh. Assuming that the gas price will raise in future, fuel oil usage percentage at marginal point where the annual fuel cost of the heavy oil-fired CCPP is equal to that of the conventional thermal power plant is calculated under the gas price as a parameter.

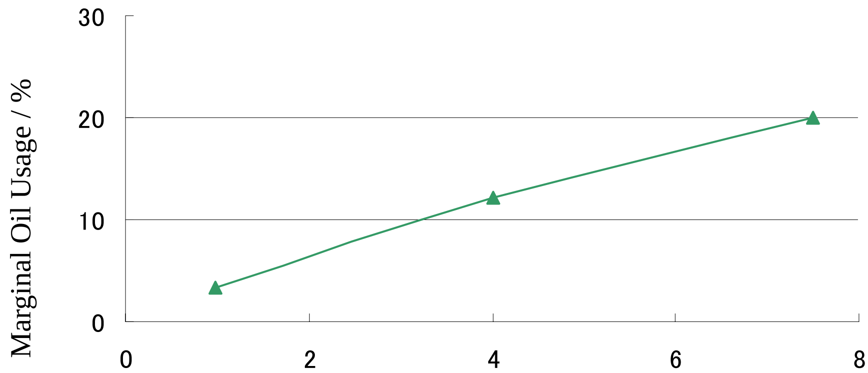


Figure I-4-7-2 Marginal fuel oil usage in CCPP

When gas price is the local price (0.98$/GJ) in Bangladesh, the annual fuel cost of heavy oil-fired CCPP will not be lower than that of the conventional thermal power plant unless the fuel oil usage is exceed 3%. Otherwise, the annual fuel cost will be higher than that of the conventional thermal power plant. In other words, if the gas price is kept at the level of the present local price in Bangladesh, the application of the CCPP is feasible only when gas supply is ensured throughout the plant operation period.
In the meantime, if the gas price has reached to the international price level, the thermal efficacy becomes more important for selection of the power generation facility. The heavy oil-fired CCPP are more economical than the conventional thermal power plant by about 20% oil usage. However even in this case, gas has to be supplied for 80% of fuel demand and thus means the gas is still main fuel for the Plant.

3) Feasibility in the application of gas / heavy oil-fired CCPP

Based on the technical and economical evaluation, the gas / heavy oil-fired CCPP can be described as follows, as compared to the conventional thermal power plant:

- Technically possible, but required heavy maintenance.
- The plant efficiency is reduced to the level of the conventional thermal power plant and output is reduced about 17%.
- Not appropriate for base load plant because of low availability by required frequent shutdown for cleaning of turbine blade and inspection.
- Not economical even in case small percentage of fuel usage.

Therefore, it can be concluded that application of the gas / heavy oil-fired CCPP to this Bheramara CCPP is not recommendable.

(2) Evaluation of gas / diesel oil-fired CCPP

There are many CCPPs with diesel oil back up system because those can generate power even in case of gas supply shut down. In this section, it is also evaluated that the feasibility of continuous diesel oil fired by CCPP.

1) Technical evaluation of heavy oil-fired CCPP

When diesel oil is used as fuel of gas turbine, as same as heavy oil fired described previous section, the low-melting point compound such as the vanadium, sodium and potassium contained in diesel oil causes performance degradation, hot corrosion of the parts and plugging of the cooling hole of the blade.

As for performance degradation, since the combustion temperature is reduced for operation of CCPP, CCPP output is reduced by about 17% and plant efficiency is reduced by about 15% shown in Table I-4-7-6. These are significantly influenced in the F class gas turbine which is operated higher combustion temperature and has complicated cooling structure in its blade.

Table I-4-7-6 Performance of Diesel oil-fired CCPP (F class)

	Gas	Diesel Oil
CCPP net power output / MW	360MW	310MW
CCPP Efficiency / %	56.0	48.0

Note) Ambient temperature is 35°C.

And as described in Section 4.5, in relation to the transportation and storage of diesel oil it is required to assure transportation capacity between the Khulna oil depots (owned by Bangladesh Petroleum Corporation) to the Bheramra CCPP and to equip sufficient unloading capacity in the Bherarma CCPP.

2) Economical Evaluation

a. Investment

When the Plant equip the diesel oil firing system as buck up purpose, the estimated investment cost of gas / diesel oil CCPP is increased by the following items.

Table I-4-7-7 Estimated investment cost related to diesel oil firing system

Additional facility	Estimated Additional Cost / mil.USD
Oil Storage Tank	5.0
Oil unloading and piping system	1.7
Increase capacity of water treatment system	2.3
Increase capacity of waste water treatment system	1.2
Total	10.2

This cost is about 2.5% of the total EPC cost for the Bheramra CCPP and thus there would be little cost impact.
On the other hand, in case of continuous diesel oil firing, the capacity of the unloading facility should be increased to 80kl/hr and the capacity of the oil storage tanks should be increased to two 50,000 kl tanks, which leads to significant cost increase.

b. Operation and Maintenance Cost
Assuming the local fuel cost and 310MW, 70% plant load factor, diesel oil firing will require 177 million USD for annual fuel cost, on the other hand gas firing will require only 12 million USD. This 177 million USD is almost same as the total fuel cost of BPDB in 2005-2006, therefore financing of it seems to face difficulty.
As for maintenance cost, in case of the diesel oil-fired CCPP, life time and maintenance interval of the hot parts of the gas turbine will be 0.7 times comparing the gas fired CCPP. It leads maintenance cost of hot parts will be 1.5 time, thus additional 4 million USD will be required annually.

3) Environmental Aspect
During diesel oil firing SOx is emitted which is not emitted during gas firing. And more NOx is emitted comparing gas firing even equipped water injection system to reduce NOx. Detail emission level is specified in Table I-5-5-4 of Section 5.5.5.

4) Feasibility of the Diesel Oil Firing System
From technical, economical evaluation and environmental aspect, the gas / diesel oil fired CCPP has following feature comparing gas fired CCPP.

- Gas / diesel fired CCPP can assure generation capacity even in case of gas supply shut down.
- Comparing heavy oil fired CCPP, there are many CCPP with diesel oil firing system, however the technical requirement might be same level and thus in almost CCPP with diesel oil firing system, it is used as back up purpose.
- Continuous diesel oil firing requires huge fuel cost and there might be high possibility to stop operation of the Plant resulting from the financial difficulty.
- SOx emission might impact on the environment.

Therefore, in this Bheramara CCPP Project, it is appropriate that the diesel oil firing system is equipped as only back up purpose.

(3) Recommendation on Fuel Flexibility

From technical, economical evaluation and environmental aspect described above it is not feasible to utilize heavy oil and diesel oil as main alternative fuel to gas. Therefore the sufficient gas supply is mandatory requirement for realization of the Bherarma CCPP Project and as recommendation on fuel flexibility, it is recommended that the Bheramra CCPP should be equipped the diesel oil firing system as back up purpose.

4.7.2 Selection of Combined Cycle Power Plant Technology

(1) Comparison of Output and Efficiency

At the beginning of the Study, the rated output of this project is set at 450 MW. Two options are normally available for the gas turbine to be used; the E-class gas turbine with a turbine inlet temperature of 1,000°C and the F-class gas turbine with a turbine inlet temperature of 1,300°C. The following Tables I-4-7-8 and I-4-7-9 show the output and efficiency under the ISO conditions (15°C, 1013 hPa and 60% humidity) of the candidate CCPP of the four major manufacturer (in case of one-through condenser is applied). When the E-class is adopted, two gas turbines will be used. When the F-class is adopted, one gas turbine will be used.

Table I-4-7-8 ISO Performance of the assumed E-class CCPP

	Model	Output / MW	Efficiency (LHV) / %
GE	S209E	391.4	52.7
MHI	MPCP2 (M701)	426.6	51.6
Siemens	SCC5-2000E 2 x 1	505.0	52.5
Siemens	SCC5-3000E 2 x 1	576.0	56.3
Alstom	KA13E2-2	507.4	53.0

(source) Gas Turbine World 2007-8 GTW Handbook

Table I-4-7-9 ISO Performance of the assumed F-class CCPP

	Model	Output / MW	Efficiency (LHV) / %
GE	S109FA	390.8	56.7
GE	S109FB	430.0	57.9
MHI	MPCP1(M701F)	464.5	59.5
Siemens	SCC5-4000F	416.0	58.2
Alstom	KA26-1	424.0	58.3

(source) Gas Turbine World 2007-8 GTW Handbook

As shown above, the output of CCPP varies according to the type and manufacturer of the gas turbine.

The output under site conditions can be approximately calculated as follows: The output of the E-class CCPP is estimated at about 360 MW to 530 MW and the output of the F-class CCPP is estimated at about 380 MW to 420 MW. In the case of the E-class CCPP, the output of 450 MW can be ensured by the models of two manufacturers; whereas the output of 450 MW cannot be ensured by any of the models in the case of the F-class CCPP. Thus, when the output of 450 MW or more is assumed as the minimum requirements for the bid, there is a competition between a maximum of two manufacturers and we consider that adequate competition is not likely to be introduced.

As shown in Tables I-4-7-8 and I-4-7-9, the efficiency is 52% for E-class CCPP (except for the Siemens SCC-3000E 2 x 1), and about 58% for F-class CCPP. Assuming that the output is 360 MW and the annual operation time is 8,000 hours, the annual fuel consumption of the E-class CCPP is estimated as about 18.1 GCF and that of the F-class CCPP is estimated as about 16.3 GCF. This shows that the F-class CCPP provide an annual gas savings of 1.8 GCF, as compared to the E-class CCPP.

In terms of annual fuel gas cost, this comes to an annual savings of about 1.7 million USD on the basis of local gas price in Bangladesh and is about 12.7 million USD on an international basis. The higher gas price, the more economical the F-class CCPP becomes.

(2) Comparison of EPC price

The following shows the general EPC price of each of the E- and F-class CCPP. The EPC price shown below has been estimated on the basis of the FOB price given in the Gas Turbine World 2007-2008 GTW Handbook. For the details on the budget plan of this project, see the Chapter 8. Comparison of the EPC price per kW (USD/kW) reveals that the E-class CCPP are slightly cheaper, as indicated in Tables I-4-7-10 and I-4-7-11.

Table I-4-7-10 Assumed price of E-class CCPP (as of June 2008)

	Model	Output / MW	FOB Price * / mil. USD	Assumed EPC Price / mil. USD	Assumed EPC Price per kW / USD/kW
GE	S209E	391.4	185.2	353.9	904
MHI	MPCP2 (M701)	426.6	191.7	366.3	872
Siemens	SCC5-2000E 2 x 1	505.0	223.2	426.5	845
Siemens	SCC5-3000E 2 x 1	576.0	262.9	502.4	872
Alstom	KA13E2-2	507.4	225.9	431.7	851
Average		481.3	217.8	416.2	869

(source) Marked (*) is extracted from Gas Turbine World 2007-8 GTW Handbook. Assumed prices are estimated by the Study Team.

Table I-4-7-11 Assumed price of F-class CCPP (as of June 2008)

	Model	FOB Price / mil. USD	Assumed EPC Price / mil. USD	Assumed EPC Price per kW / USD/kW
GE	S109FA	197.9	360.2	922
GE	S109FB	214.8	390.9	909
MHI	MPCP1(M701F)	220.4	401.1	978
Siemens	SCC5-4000F	216.9	394.8	949
Alstom	KA26-1	220.7	401.7	947
Average		214.1	389.7	941

(source) Marked (*) is extracted from Gas Turbine World 2007-8 GTW Handbook. Assumed prices are estimated by the Study Team.

(3) Economical evaluation

In the study of the preceding section, E-class CCPP are slightly more advantageous in terms of EPC price per kW (USD/kW), but more efficient F-class CCPP have greater advantages in terms of operation costs. Thus, the leveled generation cost was calculated with consideration given to both the equipment investment cost and operation cost, whereby an economical evaluation was achieved. Siemens' models were adopted for our comparative study.

1) Technical assumptions

This comparative evaluation was conducted under the following assumption with consideration given to the Gas Turbine World 2007-2008 GTW Handbook and records under similar project: Gas price is important in evaluating the economy throughout the life cycle of the plant. The current local price in Bangladesh is kept at one eighth the international price according to the government policy. In the meantime, it is expected to be an increase in the percentage of production by the international oil companies (IOC) and an accompanying rise in local gas price. Thus, the following study was made on the current local price of $0.98/GJ, the international price of $7.5/GJ, and the price of $2.4/GJ which BPDB use as reference future gas price.

Table I-4-7-12 Technical assumption for economic comparison between E class and F class CCPP

Model	Siemens SCC5-4000F	Siemens SCC5-2000E 2 x 1	
GT class	F class	E class	
Configuration (GT-HRSG-ST)	1-1-1	2-2-1	
Net Plant Output / MW	412.7	501.6	ISO condition
Net Plant Heat Rate / %	57.7	52.1	ISO condition
Plant Factor / %	70	70	
Service Period / years	30	30	
EPC Cost / mil.USD	394.9	426.5	
Gas Price (Local) / $/GJ	0.98	0.98	As of 2007
Gas Price (Assumed) / $/GJ	2.4	2.4	
Gas Price (International) / $/GJ	7.5	7.5	As of Sep. 2007
Fixed O&M Cost / $/kW/yr	8.8	8.8	
Variable O&M Cost / $/MWhr	4.0	4.0	
Annual interest / %	5.5	5.5	
Escalation rate / %	6.12	6.12	average CPI in last 5yrs
Depreciation period / years	30	30	

2) Estimation results

The leveled generation cost has been obtained by calculating the annual expenses for the operation period of the capital recovery cost and O&M costs such as fuel cost. The average capital recovery cost is higher in the F-class CCPP than in E-class CCPP. Even at the current local gas price, the leveled generation cost is lower in the F-class CCPP than in E-class CCPP. This difference is more conspicuous when the gas price is higher. In terms of the annual generation cost, the F-class CCPP have been shown to be more economical by about 27.5 million USD per year up to a gas price increase of 7.5$/GJ.

Thus, from an economical view point, the F-class CCPP can be recommended as the Bheramara combined cycle power plant (CCPP) due to its higher efficiency and further reduction in fuel consumption.

Table I-4-7-13 Economical comparison between E- and F-class CCPP

Model		Siemens SCC5-4000F (A)	Siemens SCC5-2000E 2 x 1 (B)	Deference (=A-B)
Levelized Capital Recovery Cost / US cent/kWhr		1.26	1.12	0.9
Levelized Variable O&M Cost / US cent/kWhr		0.85	0.85	0
Levelized Fixed O&M Cost / US cent/kWhr		0.31	0.31	0
Levelized Fuel Cost / US cent/kWhr	Local Gas Price	1.49	1.65	-0.16
	Assumed Gas Price	3.66	4.05	-0.39
	International Gas Price	11.4	12.7	-1.3
Levelized Generation Cost / US cent/kWhr	Local Gas Price	3.91	3.93	-0.02
	Assumed Gas Price	6.08	6.33	-0.25
	International Gas Price	13.9	14.9	-1.1
Levelized Annual Generation Cost / mil.USD/yr *	Local Gas Price	99.0	99.6	-0.5
	Assumed Gas Price	153.8	160.2	-6.4
	International Gas Price	350.6	378.1	-27.5

Note) At the marked (*) calculation annual generation is assumed as 2.53 TWhr (= 412.7 MW x 8760 hrs x 0.7) for both CCPP.

(4) Comparison of carbon dioxide emissions

The greenhouse gases produced by power plant mainly consists of the carbon dioxide produced from fuel combustion. The carbon dioxide is emitted by combustion of the fossil fuel such as coal, petroleum, and natural gas. Thus, improvement of the thermal efficiency of the power plant contributes to fuel savings as well as to conservation of limited natural resources and reductions in the emission of carbon dioxide. Thus, for the implementation of this project, introduction of F-class CCPP of higher efficiency will reduce the amount of fuel to be used, and hence reduce the amount of carbon dioxide to be emitted.

1) Technical Assumptions

Estimation has been made to calculate the carbon dioxide emissions for the following power plant.

Base case: E-class GT simple cycle power plant
Project case A: E-class CCPP
Project case B: F-class CCPP

Table I-4-7-14 shows the technical assumptions. Annual power generation at 70% plant factor in the project case B is used as baseline.

Table I-4-7-14 Technical assumptions for estimation of carbon dioxide emissions

	Base Case	Project Case A	Project Case B
Plant System	E-class GT Simple Cycle	E-class GT Combined Cycle	F-class GT Combined Cycle
Model	Siemens SGT5-2000E x 3	Siemens SCC5-2000E 2 x 1	Siemens SCC5-4000F
Net Output /MW (ISO)	504.0 MW	505.0 MW	416.0 MW
Annual Power Generation /GWhr	Same as Project Case B	Same as Project Case B	2,551 GWhr (Plant factor =70％)
Efficiency/%(LHV)	34.7%	52.5%	58.3%
Fuel	Natural Gas	Natural Gas	Natural Gas

2) Calculation formula

The following shows the formula for calculating the emission of greenhouse gases.

Emission of greenhouse gas (t-CO_2/year)
= fuel consumption (TJ)
x carbon emission factor (tC/TJ)
x carbon content (kg/GJ)
x carbon oxidation factor
x carbon conversion factor

The fuel consumption is calculated using the value shown in Table I-4-7-15. The carbon content, carbon oxidation factor and carbon conversion factor are based on the IPCC guideline, which is given in Table I-4-7-15.

Table I-4-7-15 List of IPCC coefficients

	Natural Gas
Carbon Content/Kg/GJ	15.3
Carbon Oxidation Factor	0.995
Conversion Factor	44/12

(source) IPCC Guideline for National Greenhouse Gas Inventories Reference Manual

3) Calculation results

Table I-4-7-16 shows the effects of reducing greenhouse gas emissions for each case.

Table I-4-7-16 Effects of reducing greenhouse gas emissions

	Base Case	Project Case A	Project Case B
Plant System	E-class GT Simple Cycle	E-class GT Combined Cycle	F-class GT Combined Cycle
Annual Energy Consumption/TJ/yr	26,470	17,495	15,755
Annual CO_2 Discharge /t-CO_2/yr	1,477,517	976,569	879,414
Annual CO_2 Reduction /t-CO_2/yr	-	500,948	598,103

The above table shows that the annual reduction of carbon dioxide is 500,948 t-CO_2 for the E-class CCPP and is 598,103 t-CO_2 for the F-class CCPP. The percentage of reduction is 34 and 40%, respectively. Further, comparison between the E-class and F-class CCPP shows that the reduction volume is 97,155 t-CO_2 and the percentage of reduction is 10%.

Thus, introduction of the CCPP for the Project will result in a reduction of a considerable amount of carbon dioxide emissions, as compared to the simple cycle power plant having been used in Bangladesh. Moreover, adoption of the F-class CCPP with greater reduction ability is preferred from the viewpoint of preventing global warming.

(5) Influence upon the power grid system

E-class CCPP is composed of two gas turbine generators, and one steam turbine generator. The maximum generator capacity is about 190 MW (at the atmospheric temperature of 15°C). On the other hand, the F-class CCPP are composed of one gas turbine generator, and one steam turbine generator. The maximum generator capacity is about 310 MW (at the atmospheric temperature of 15°C).

When the influence upon the power grid system is taken into account at the time of tripping of the generator due to some failure, the capacity of each generator is preferred to be the smaller. However, the influence upon the power grid system is maximized when the CCPP have been fully tripped. The result of static analysis of the power grid system discussed in Section 4.4.3 of the Main Report in Volume 1 has verified that the power flow and voltage are within the permissible range even when the assumed maximum plant capacity is 575 MW.

Accordingly, the influence of the E-class and F-class CCPP on the power grid system is within the permissible range in both cases, despite there is difference in degree of influence resulting from the difference in the capacity of the generator. Therefore, both classes CCPP are applicable for the Project.

(6) Limitation by Heavy Equipment Transportation

At the beginning of the planning of the equipment transportation during construction, it is important to evaluate whether it is possible to transport the heaviest equipment. In the CCPP, the heaviest equipment is a gas turbine. The E-class gas turbine weighs between 200 to 339 tons, and the F-class gas turbine weighs between 339 to 418 tons. According to the study in Section 4.8, it is possible to transport the heavy equipment by river. In such case it is planned to use barges which can carry up to 600 ton. Therefore the technical difficulty of transportation is same level for both classes because such barges can carry both class of gas turbine.

(7) Conclusion

Table I-4-7-17 shows summary of what described above. The F-class CCPP is recommendable for the Bheramara CCPP Project through technical and economical evaluation and taking into account environmental aspect.

Table I-4-7-17 Summary of comparison of E class CCPP and F class CCPP

	F class CCPP	E class CCPP	Recommendation
Output @site condition	380 – 420 MW	360-530 MW (Only 2 OEMs offer over 450MW CCPP)	Competitive bidding is restricted by the minimum capacity requirement as 450 MW.
Efficiency (@ISO, in case of one-through condenser)	58%	52%	F class CCPP has 6 % higher efficiency.
Estimated EPC Cost	390 mil.USD (937USD/kW)	416mil.USD (869USD/kW)	E class CCPP's unit price (USD/kW) is slightly lower.
Generation Cost (Unit Gas Price = 2.4USD/GJ)	3.66 cent/kWhr	4.05 cent/kWhr	F class CCPP is more economical.
CO_2 emission (per annual Power generation)	Base	Minus (-) 100,000 ton CO_2/yr	F class CCPP emits less CO_2.
Influence on Grid	Within allowable limit	Within allowable limit	Same level
Limitation by Transportation	GT weight 339～418 ton	GT weight 200～339 ton	Same level (Limitation of barge is 600 ton.)

4.7.3 Study on Shaft Configuration

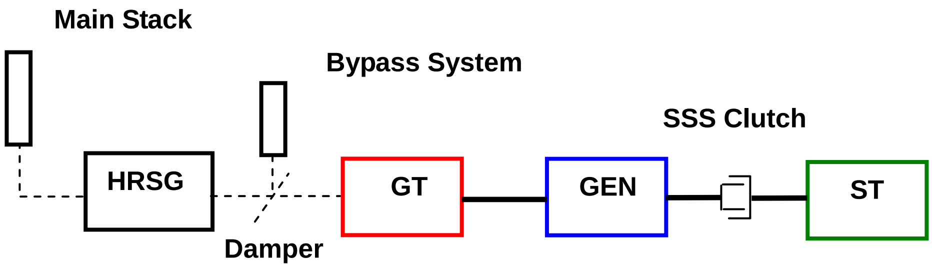
(1) Type of Shaft Configuration

Here made is the comparison study on the type of the shaft configuration of the combined cycle power plant (hereinafter to be collectively called as CCPP) comprised of the one (1) gas turbine, one (1) heat recovery steam generator (hereinafter to be collectively called as HRSG), one (1) steam turbine and generator(s). Basically, there are two (2) types of shaft configurations. One is called single-shaft configuration where the gas turbine, a steam turbine and a generator are connected on the same shaft. The other is called multi-shaft configuration where the gas turbine/generator shaft and the steam turbine/generator are separate.

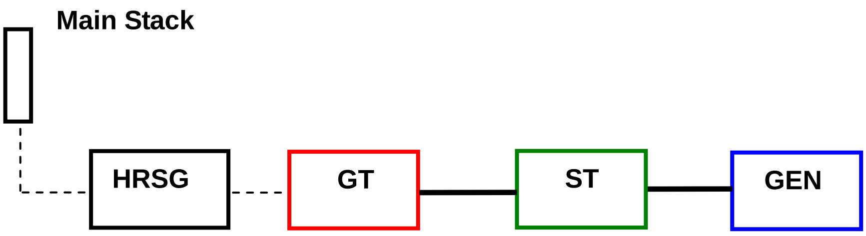
The single-shaft configuration is classified into two (2) types of configurations depending upon with and without a SSS clutch and a bypass system. In case of the former configuration, the power train is arranged in order of the gas turbine, the generator and the steam turbine. The SSS clutch is of auto-engagement and disengagement type and is located between the generator and the steam turbine. In case of the latter configuration, the power train is

commonly arranged in order the gas turbine, the steam turbine and generator.
In case of the multi-shaft type, two (2) types of CCPP configurations with and without the bypass system could be considered. These four (4) types of CCPP configurations are as depicted below:

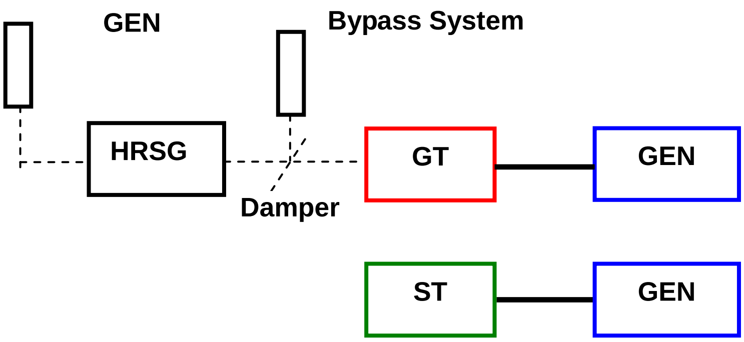
Single-Shaft CCPP with SSS Clutch and Bypass System

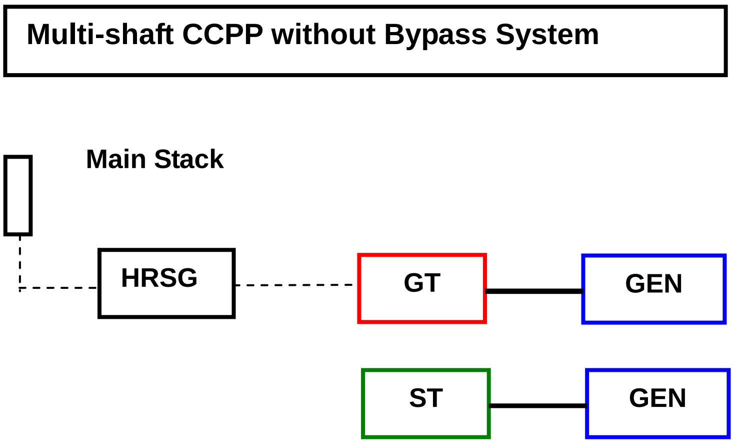


Single-Shaft CCPP without SSS Clutch



Multi-shaft CCPP with Bypass System





As shown above, in case of the single-shaft CCPP, one (1) large capacity generator common to both gas and steam turbines is employed. While in case of the multi-shaft CCPP, two (2) generators are individually employed for the gas and steam turbines. In this case, one is the plant configuration with the bypass system consisting of a bypass stack and a damper, which are installed between the gas turbine and HRSG to allow for the gas turbine/generator to operate as a simple cycle. Other one is the plant configuration without the bypass system.
The comparison study is performed from the viewpoints of thermal efficiency, operational flexibility, operability, start-up steam and auxiliary power requirement, application experiences, operating reliability, maintainability, installation footprint area requirement, construction cost, generation cost and transportation among above four (4) types of CCPP shaft configurations. The details of the bypass system are described in the sub-section 5.7 (Exhaust Gas Bypass System) hereon.

(2) Plant Thermal Efficiency
The single-shaft configuration is equipped with one (1) larger size generator, while two (2) smaller sizes of generators are employed in the multi-shaft configuration. In case of the configuration with the bypass system, the leakage from the bypass system of the exhaust gas will influence on the plant efficiency. It is reportedly said that the leakage over the life time of the plant is 0.5 to 1.5%. This means that the steam turbine efficiency drops by 0.5 to 1.5%. Consequentially, the thermal efficiency of the plant with the bypass system drops by 0.17 to 0.50% compared with the plant without it. Therefore, the plant thermal efficiencies of the four (4) configurations are as estimated below considering that the efficiency of the larger capacity generator is higher by some 0.1%. The heat loss due to the clutch is considered to be negligible small.

Type of Configuration	SS CCPP w SSS and BS	SS CCPP w/o SSS and BS	MS CCPP w BS	MS CCPP w/o BS
Plant Thermal Efficiency (%)	Δ0.17~0.50	100	Δ0.27~0.60	Δ0.1

Where,

SS CCPP w SSS and BS	Single-shaft CCPP with Clutch and Bypass System
SS CCPP w/o SSS and BS	Single-shaft CCPP without Clutch and Bypass System
MS CCPP w BS	Multi-shaft CCPP with Bypass System
MS CCPP w/o BS	Multi-shaft CCPP without Bypass System

(3) Operational Flexibility
In case of the single-shaft CCPP without the clutch, the plant could not be operated unless the

components of the gas turbine, the heat recovery steam generator, steam turbine and the generator are all healthy. While, the single-shaft CCPP with the clutch and bypass system could be operated on a simple cycle mode with isolation of the steam turbine by disengaging the clutch even if any components of the bottoming system consisting of a HRSG, a steam turbine and a steam turbine generator is out of order due to any reasons. The exhaust gas from the gas turbine can be discharged into atmosphere through the bypass system.

In case of the multi-shaft configuration, if the bypass system is equipped, the gas turbine/generator could be operated as a simple cycle similarly to the single-shaft configuration CCPP with the clutch.

Unless the bypass stack is equipped, the plant behaves as if it were of a single-shaft type without the clutch. However, the plant could be operated on a simple cycle mode by dumping the generated steam into the condenser for not so long time only if the HRSG and the condenser are both in healthy conditions.

Thus, the CCPP with the bypass system, whichever the shaft configuration is, will be more flexible in terms of operability than without the bypass system. There is always no difference in terms of operational flexibility between both types of shaft configurations without the bypass system.

(4) Operability

The CCPP could be operated only by automatic adjustment of the fuel flow into the gas turbine and the operation cycle of start-up, steady operation and shut-down could be fully automated irrespective of the type of the shaft configuration. The SSS clutch is of a self-shift and synchronous type. There is, therefore, no essential difference with the operability between both types of shaft configurations. The operational sequence of the multi-shaft CCPP may be slightly complicated compared to the single-shaft CCPP because of more numbers of components.

(5) Start-up Steam and Auxiliary Power Requirements

In case of the multi-shaft CCPP or the single-shaft CCPP with the clutch, the gas turbine can be started up together with the HRSG separately from the steam turbine/generator. After a certain period of the time, the necessary steam for start-up can be available from the HRSG and then the steam turbine/generator can be started up with own steam for flow passage cooling and gland sealing.

In case of the single-shaft configuration without the clutch, however, the steam for the flow passage cooling and gland sealing of the steam turbine which must be started up together with the gas turbine is required from any external sources. For the purpose, any auxiliary steam from the existing boilers or a standalone auxiliary boiler will be needed.

In case of the single-shaft configuration without the clutch, the power requirement for the starting device is approximately 2.5% of the gas turbine power output, while it is approximately 2.0% in cases of other three (3) types of CCPPs.

There is no difference with the auxiliary power requirements among the types of CCPPs except for the starting device of the shaft train.

(6) Application Experiences

As shown in the attached Tables I-4-4-18 and 19, there are many application experiences with both shaft configuration types of CCPPs. It is understood that both types of shaft configurations are technically feasible without any technical difficulties.

Table I-4-4-20 is the application experience list of the CCPPs with the SSS clutches of which power transmitting capacities are more than 100 MW. From this table, it is found that the more application experience with the SSS clutches is limited to two (2) manufacturers.

(7) Operating Reliability

The plant operating reliability of each type of CCPP could be evaluated by the plant reliability factor to be calculated with the reliability factors of the main equipment which are assumed as shown below:

Gas turbine:	A1 = 97.5%
Bypass system:	A2 = 98.0%
Heat recovery steam generator:	A3 = 98.5%
Steam turbine:	A4 = 99.0%
Gas turbine generator and transformer:	A5 = 99.5%
Steam turbine generator and transformer:	A6 = 99.5%
SSS clutch:	A7 = 99.8%

The followings are the theoretically calculated plant operating reliabilities on an hour basis of the single-shaft CCPP without the clutch as $PORH_S$ and with the clutch as $PORH_{SS}$, the multi-shaft CCPP without the bypass system as $PORH_M$ and the multi-shaft CCPP with the bypass system as $PORH_{MB}$.

$PORH_S$ = A1×A3×A4×A5 = 0.975×0.985×0.990×0.995 = 0.946 = 94.60 %

$PORH_{SS}$ = A1×A2×A3 ×A4 ×A5 ×A7 + A1×A2×A5×A7×(1-A3×A4)
= 0.975×0.980×0.985×0.990×0.995×0.998 + 0.975×0.980×0.998×(1- 0.985×0.990)
= 0.9252 + 0.0236 = 0.9488 = 94.88 %

$PORH_M$ = A1×A3×A4×A5×A6 = 0.975×0.985×0.990×0.995×0.995 = 0.9413 = 94.13 %

$PORH_{MB}$ = A1×A2×A3×A4×A5×A6 + A1×A2×A5× (1-A3×A4×A6)
=0.975×0.980×0.985×0.990×0.995×0.995+0.975×0.980×0.995×(1-0.985×0.990×0.995)=
0.9225 + 0.0283 = 0.9507 = 95.07 %

The figure of 92.52% out of the plant operating reliability (94.88%) of the single-shaft CCPP with the clutch shows the operating reliability, under which all components will be healthily operated. While, the figure of 2.36% is the operating reliability, under which only the gas turbine/generator will be operated due to any troubles of the bottoming system. The similar thing is applicable to the figure of $PORH_{MB}$.
By the above calculation results, the following relationship could be predicted among operating reliabilities on an hour basis of the four (4) types of CCPPs.

$PORH_{MB}$ (95.07 %) > $PORH_{SS}$ (94.88 %) >$PORH_S$ (94.60 %) > $PORH_M$ (94.13 %)

It is found from this relationship that the plant operating reliability ($PORH_{MB}$) of the multi-shaft CCPP with the bypass system is slightly higher than any other types of CCPPs. However, its advantage is not so high compared with other types of CCPPs.
Similarly, the plant operating reliability on an energy basis (PORE) could be theoretically calculated on the assumption that the power output of the gas turbine/generator unit is two third the plant total power output. In case of the CCPP with the bypass system, the power output loss of 0.17% due to the exhaust gas leakage is considered. Besides, it is considered that the multi-shaft CCPP is equipped with the smaller capacity generator with less efficiency. The calculation results are as shown below:

$PORE_S$: 94.60 %

$PORE_{SS}$: 93.94 %
$PORE_{M}$: 94.03 %
$PORE_{MB}$: 93.88 %

As the results, it was found that the plant operating reliability ($PORH_S$) of the single-shaft CCPP without the clutch and bypass system is slightly higher than any other types of CCPPs. However, its advantage is not so high compared with other types of CCPPs.
Thus, it is difficult to say from the above analysis results that the multi-shaft CCPP with the bypass system is very advantageous in terms of the plant operating reliability. The reason is such that the plant total operating reliability may be lessened due to more equipment to be put into operation.

(8) Maintenance Cost
Compared with the single-shaft CCPP, the multi-shaft CCPP is equipped with additional components such as a generator, a step-up transformer, a lubricating and control oil systems, a bypass stack, a bypass stack silencer, and an exhaust gas damper. Therefore, it is envisaged that the maintenance of the multi-shaft CCPP needs more man-hour requirement and is costly.

(9) Footprint Area for Instruction
As mentioned in the previous paragraph, since the multi-shaft CCPP is equipped with more facilities than the single-shaft CCPP, more footprint area is needed for their installation. In addition, the space utilization effect is inferior because the gas turbine/generator and steam turbine/generator are severally installed. It is foreseen from our experiences that the footprint area for installation of the multi-shaft CCPP power train is more or less larger by 15 ~ 25% than the single-shaft CCPP depending upon installation of the bypass system. The larger footprint area for installation of equipment means larger amount of civil, architectural and erection works, which in turn means higher cost. The Figure I-4-7-3 and I-4-7-4 attached hereon show the typical plan drawings of single-shaft CCPP power train without the clutch and multi-shaft CCPP power train with bypass system using F-class gas turbine.
In case of the single-shaft CCPP power train with the clutch and bypass system, the length in the longer direction is supposed to be longer by some 20 m compared to the layout shown with Figure I-4-7-3. Therefore, the footprint area for installation comes close to that of the multi-shaft CCPP power train with bypass system.

(10) Phased Construction
The multi-shaft configuration with the bypass system has the special feature that the phased construction can be available. The completion time of the gas turbine package is normally faster than the bottoming system, which means that it will be put into commercial operation in advance. This feature is more advantageous for the project which must cope with steeply increasing power demand.

(11) Construction Cost
The multi-shaft CCPP is constituted of more number of components than single shaft CCPP as mentioned in previous paragraphs. Therefore, it is easily predicted that its construction cost will be higher compared with the single-shaft CCPP. The attached Table I-4-7-21 shows the computer estimated construction costs for the typical models of multi-shaft configuration CCPPs, and Table I-4-7-22 is for typical models of single-shaft configuration CCPPs.
The scope of equipment to be covered with the computer software is limited. For example, the switchyard equipment and its construction cost, cost for consumable spare parts during a certain period and the transportation cost for special conditions are not included. Therefore, it is not always said that the values of said estimated construction costs correctly reflect the

construction costs for this Project. However, the cost relative difference between them could be used as a referential value for this study.
As shown in these tables, the costs of other three (3) types of CCPPs against the SS CCPP w/o SSS and BS are summarized as tabulated below:

SS CCPP w SSS and BS	plus 2.2 %
MS CCPP w/o BS	plus 4.2 %
MS CCPP w BS	plus 6.1 %

(12) Power Generation Cost
The power generation costs of other three (3) types of CCPPs against the SS CCPP w/o SSS and BS could be calculated as shown below:

1) Fuel cost
Fuel cost (fuel consumption) is proportional to the plant operating reliability on an hour basis. Therefore, fuel costs of other three (3) types of CCPPs against the SS CCPP w/o SSS and BS are estimated as tabulated below:

SS CCPP w SSS and BS	plus 0.30 %
MS CCPP w/o BS	minus 0.50 %
MS CCPP w BS	plus 0.50 %

2) Capital recovery cost
The capital recovery cost proportional to the construction cost can be estimated as shown below from Table I-4-7-30 and Table I-4-7-21.

SS CCPP w SSS and BS	plus 2.2 %
MS CCPP w/o BS	plus 4.2 %
MS CCPP w BS	plus 6.1 %

3) Power Energy sales
The power energy sales proportional to the plant operating reliability on an energy basis is estimated as shown below from the calculation results stated in the above sub-section 5.4.7:

SS CCPP w SSS and BS	minus 0.70 %
MS CCPP w/o BS	minus 0.60 %
MS CCPP w BS	minus 0.76 %

Therefore, the power generation cost of SS CCPP w SSS and BS against the SS CCPP w/o SSS and BS can be calculated to be higher by 1.5% (= $((1 + 0.0030)\times 3/4 + (1+0.022)\times 1/4))/(1 - 0.0070) - 1.0) = 0.015$), provided that the ratio of the fuel cost to the capital recovery cost is 1.0 to 2.0 in the present electricity tariff system of Bangladesh. The generation costs of other two (2) types of CCPPs can be similarly calculated. The calculation results are as follows:

MS CCPP w/o BS	plus 1.3 %
MS CCPP w BS	plus 2.7 %

(13) Inland Transportation
The site, Bheramara, is located near by the Padma River in the inland area northwest of

Bangladesh. The inland transportation could be made by road and/or water. As the inland transportation survey results, two (2) types of manners are considered depending upon the weight, dimension and packing style of the cargos. The heavier cargos over 40 tons are to be transported by water during the wet season from July to September when the water level is high enough for transportation from Mongla port to the site. The normal cargos less than 40 tons are to be transported by road.

The weights and dimensions of the generator and step-up transformer are different due to type of the shaft configuration, while other components are common irrespective of shaft configuration. The capacity size of them of the single-shaft CCPP is larger by approximately 1.5 times than the multi-shaft CCPP. However, the heaviest cargo is deemed to be the gas turbine for the both types depending upon plant manufacturers. Therefore, there is no difference with the difficulty of the inland transportation due to the type of shaft configuration.

(14) Study Summary and Recommendation

The study results described above is simply summarized as the table attached in the next page. The yellow colored cell shows that the shaft configuration of the cell is advantageous in the related comparison item.

As shown in this table, each type of shaft configuration of CCPP has both merits and demerits. For example, if the first priority is given to the economy (thermal efficiency, construction cost, generation cost) of the project, the single-shaft CCPP without the clutch can be recommended, while the first priority is given to the operational flexibility (simple cycle operation) and operating reliability (hour basis), the multi-shaft CCPP with the bypass system can be recommended.

The single-shaft CCPP with the clutch and the bypass system is possessed of all merits of the economy and the operational flexibility and operating reliability although they are not always best in their comparison items. However, it is afraid that the fair competitive bidding could not be expected because of limitation of CCPP manufacturers of Alstom and Siemens having sufficient experience of the single-shaft CCPP with the SSS clutch.

This plant is to be constructed in the north-southern area of Bangladesh to improve the power flow imbalance in the Bangladesh Network System. For the time being, this plant is scheduled to operate by only one unit. Therefore, any power shall not be developed from the plant if it drops after the existing superannuated and small power units are demolished. However, such situation must be avoided. For the purpose, the multi-shaft configuration CCPP with the bypass system should be recommended. This type of CCPP can cope with the steeply increasing power demand of Bangladesh because the phased construction is applicable.

As a conclusion, the multi-shaft CCPP with the bypass system shall be recommendable considering the significance of construction of this type of plant as stated above. It is another reason for recommendation of it that all CCPPs introduced into Bangladesh are of same type.

Summary of Comparison Study Results on Shaft Configuration of CCCP

Comparison Item		Single-shaft CCPP		Multi-shaft CCPP	
		Without a SSS clutch	With a SSS clutch	With a bypass stack	Without a bypass stack
1. Thermal Efficiency		Base (100 %)	Δ 0.17 %	Δ 0.27 %	Δ 0.10 %
2. Operational Flexibility (Simple Cycle Operation)		Base (No)	More flexible (Yes)	More flexible (Yes)	Same (No)
3. Operability		Base	Same	Slightly complicated due to operation of more equipments	
4. Start-up Requirement	**Steam**	External auxiliary steam	Own steam	Own steam	External auxiliary steam
	Power for Starting device	App. 2.5 % of GT capa.	App. 2.0 % of GT capa.	App. 2.0 % of GT capa.	App. 2.0 % of GT capa.
5. Application Experiences		No difference (Both configurations have many experiences), however, many experiences with CCPP with SSS clutch are limited to two (2) manufacturers,			
6. Operating Reliability	**Hour basis**	Base (100 %)	+ 0.3 %	+ 0.5 %	Δ 0.5 %
	kWh basis	Base (100 %)	Δ 0.7 0%	Δ 0.76 %	Δ 0.60 %
7. Maintenance Cost		Base	Same	Slightly higher because of more equipments	
8. Footprint Area of Power Train		Base (100 %)	+ 15 %	+ 25 %	+ 10 %
9. Phased Construction		No	No	Yes	No
10. Construction Cost		Base (100 %)	+ 2.2 %	+ 6.1 %	+ 4.2 %
11. Power Generation Cost		Base (100 %)	+ 1.5 %	+ 2.7 %	+ 1.3 %
12. Inland Transportation		Base	Similar	Similar	Similar

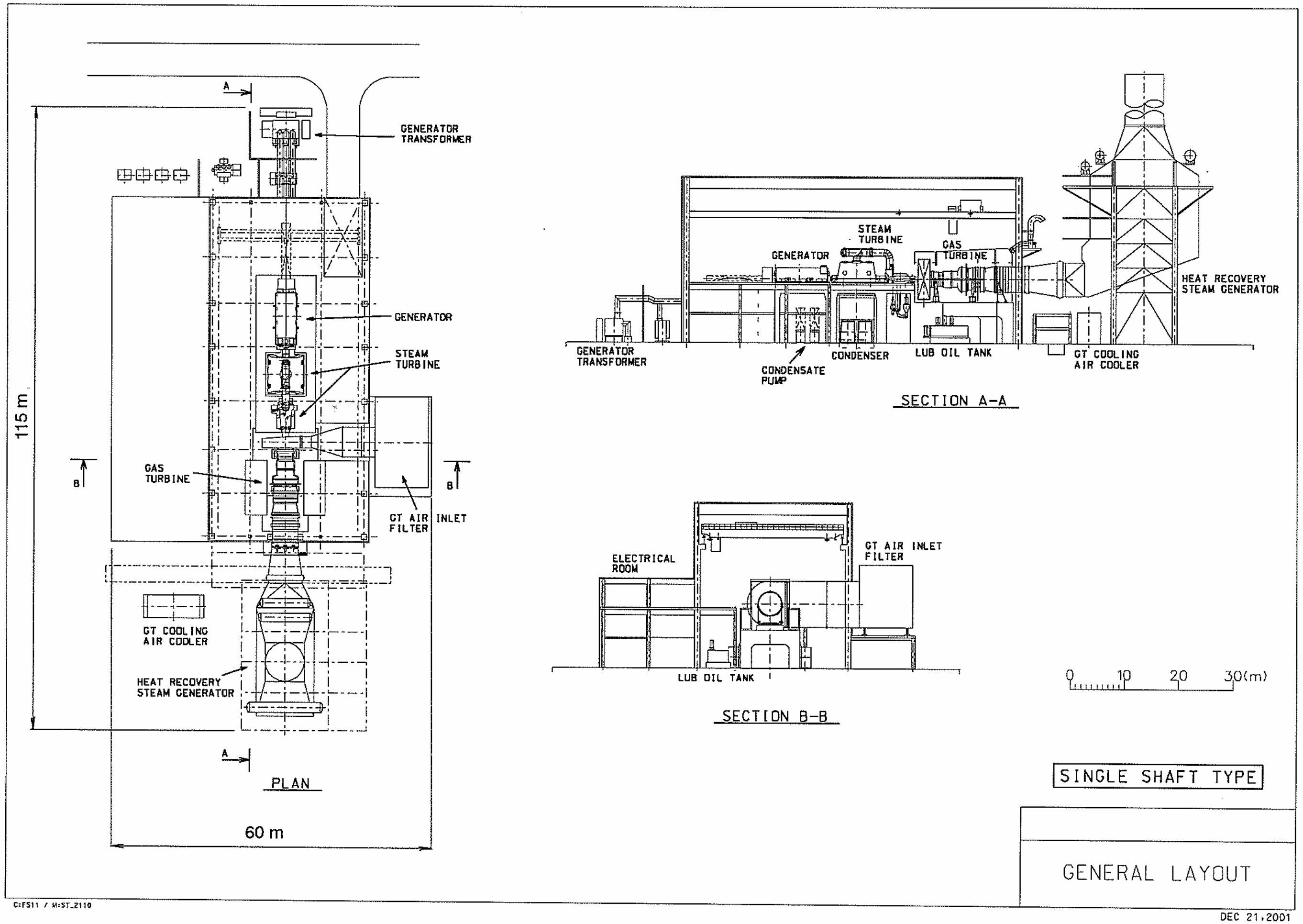


Figure I-4-7-3 Typical Layout of Single-shaft Arrangement Combined Cycle Power Plant

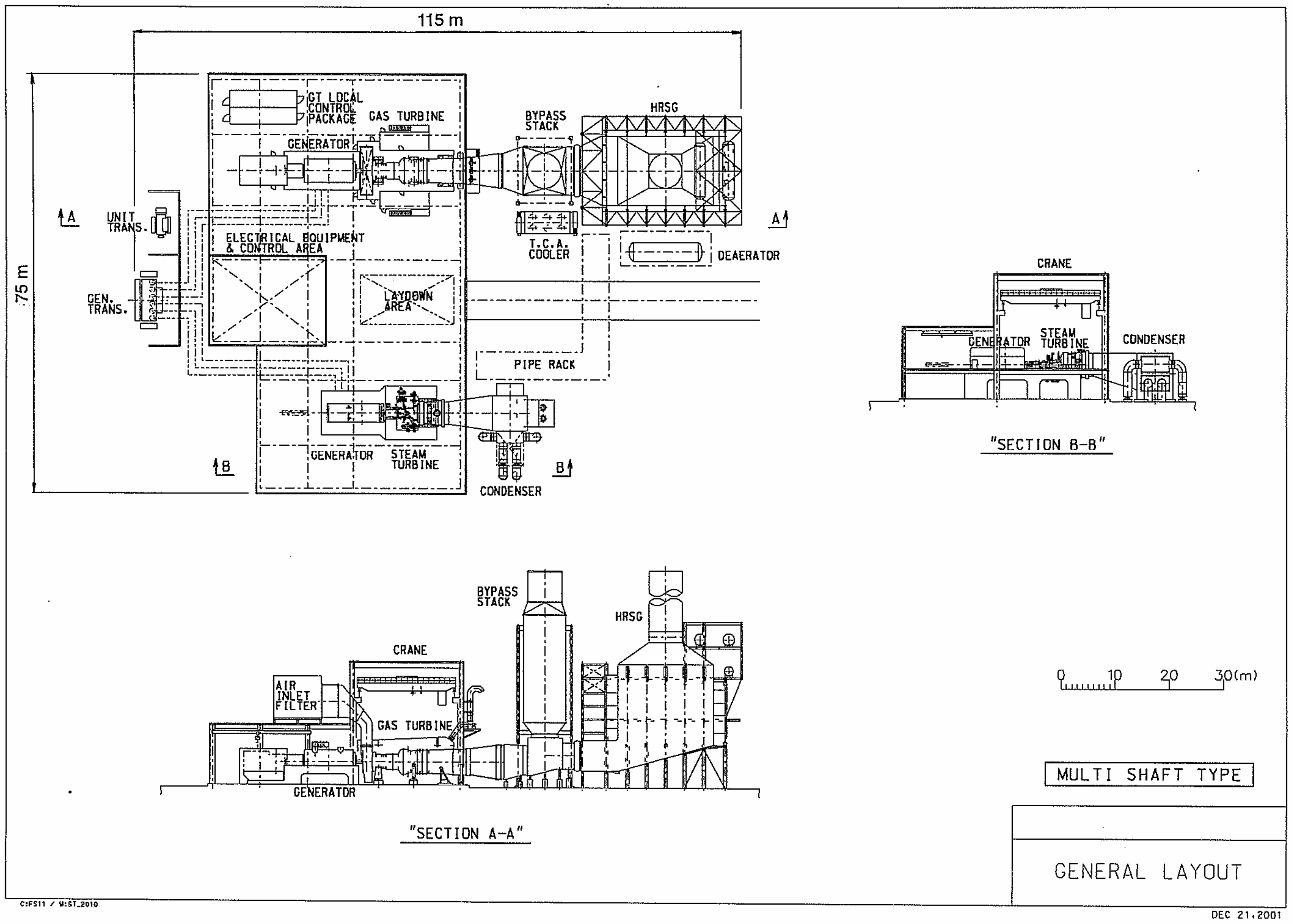


Figure I-4-7-4 Typical Layout of Multi-shaft Combined Cycle Power Plant

Table I-4-7-18 Single-shaft Combined Cycle Power Plant (above 100 MW) Experience (1/4)

Model	Plant Name	Country	Operation Year	Unit Capacity	No. of Unit
ALSTOM					
KA26-1	Castejon 2	Spain	2008	400	1
KA26-1	Cartagena	Spain	2006	400	3
KA24-1 ICS^{TM}	Monterrey III	Mexico	2003	250	4
KA26-1	San Roque	Spain	2002	400	2
KA26-1	Besos	Spain	2002	400	2
KA26-1	Bowin	Thailand	2002	350	2
KA26-1	Chiba	Japan	2002	400	1
KA26-1	Swanbank	Australia	2002	380	1
KA26-1	Bang Bo	Thailand	2002	350	1
KA26-1	Castejon	Spain	2002	380	1
KA24-1	Termobahia	Brazil	2002	185	1
KA24-1 ICS^{TM}	La Paloma	USA	2001	250	4
KA26-1	Ringsend	Ireland	2001	380	1
KA24-1 ICS^{TM}	Hermosillo	Mexico	2001	253	1
KA24-1 ICS^{TM}	Milford	USA	2001	265	2
KA24-1 ICS^{TM}	Bellingham	USA	2001	265	2
KA24-1 ICS^{TM}	Midlothian Extension	USA	2001	240	2
KA24-1 ICS^{TM}	Hays County	USA	2001	275	4
KA24-1 ICS^{TM}	Rosarito III	Mexico	2001	270	2
KA24-1 ICS^{TM}	Blackstone	USA	2001	275	2
KA24-1 ICS^{TM}	Lake Road	USA	2001	267	3
KA24-1 ICS^{TM}	Midlothian	USA	2000	250	4
KA24-1	Island Cogen	Canada	2000	250	1
KA24-1 ICS^{TM}	Monterrey	Mexico	2000	242	2
KA26-1	Shoreham	UK	2000	400	1
KA26-1	Tocopilla	Chile	1999	400	1
KA26-1	Enfield	UK	1999	400	1
KA24-1 ICS^{TM}	Agawam	USA	1999	271	1
KA11N2-1	Dighton	USA	1999	168	1
KA26-1	Taranaki	NZ	1998	360	1
KA11N2-1	Bao Shan	China	1997	150	1
KA13D	Deep	Dubai	1993	135	1
KA13D	Korneuburg	Austria	1980	128	1
KA11N	West Winsor	Canada	1995	120	1
KA11N	Orland	USA	1993	120	1

KA11	Hazleton	USA	1989	135	1
TOTAL					43

Table I-4-7-18 Single-shaft Combined Cycle Power Plant (above 100 MW) Experience (2/4)

Model	Plant Name	Country	Operation Year	Unit Capacity	No. of Unit
GE					
STAG 109 FA	Shinagawa	Japan	2001-2003	380	3
STAG 109 FA	Chiba	Japan	1998	360	4
STAG 109 FA	Akzo	NZ	1998	360	1
STAG 106FA	Baffolora	Italy	1998	110	1
STAG 107FA	Kawagoe	Japan	1998	235	7
STAG 109 FA	Yokohama	Japan	1997	350	8
STAG 107FA	Hermiston	USA	1996	213	2
STAG 107FA	Cogentrix	USA	1996	248	1
STAG 109FA	Gent	Belgium	1996	350	2
STAG 109FA	Black Point	China	1995	340	8
STAG 109FA	EPON	Netherland	1995	350	5
STAG 107F	Connah's Quey	UK	1995	350	4
STAG 107EA	Shin-Oita	Japan	1992	138	5
STAG 107F	Yanai	Japan	1990	125	6
STAG 107E	Yokkaichi	Japan	1988	112	5
STAG 109E	Futtsu	Japan	1986	165	14
TOTAL					76

Table I-4-7-18 Single-shaft Combined Cycle Power Plant (above 100 MW) Experience (3/4)

Model	Plant Name	Country	Operation Year	Unit Capacity	No. of Unit
MHI					
MPCP1(M701F)	Serervaya	Azerbaijan	2002	438	1
MPCP1(M701F)	Tuas II	Singapore	2001	360	2
MPCP1(M701F)	PPN	India	2001	348	1
MPCP1(M701F)	Saltend	UK	2000	400	3
MPCP1(M701F)	San Ishidro	Chile	1998	370	1
MPCP1(M701F)	Chiba	Japan	1999	360	4
MPCP1(M701D)	JR Kawasaki	Japan	1999	190	1
MPCP1(M501F)	Nanpu	Taiwan	2003	251	1
MPCP1(M501F)	Trans Alta	Mexico	2002	282	1
MPCP1(M501D)	Hunamachi	Japan	1999	149	1
MPCP1(M501F)	Shin-Ohita	Japan	1997	218	2
MPCP1(M501F)	Kawagoe	Japan	1997	243	7
MPCP1(M701D)	STEAG	Netherland	1997	145	1
MPCP1(M501F)	Shin-Ohita	Japan	1996	218	2
MPCP1(M501D)	Fukuyama	Japan	1996	145	1
MPCP1(M501D)	Mizushima	Japan	1995	145	2
MPCP1(M701D)	Kawasaki Steel	Japan	1988	145	1
TOTAL					32

Table I-4-7-18 Single-shaft Combined Cycle Power Plant (above 100 MW) Experience (4/4)

Model	Plant Name	Country	Operation Year	Unit Capacity	No. of Unit
Siemens					
UD 1S. V94.3A	Campo de Gibraltar	Spain	2003	385	2
GUD 1S. V94.3A	Pulau Seray	Singapore	2002	370	2
GUD 1S. V94.3A	Pulau Seray	Singapore	2002	370	2
GUD 1S. V84.3A	San Lorenzo	Philippines	2002	250	2
GUD 1S. V94.3A	Donaustadt	Austria	2001	385	1
GUD 1S. V64.3A	San Pedro	Domonican	2001	100	3
GUD 1S. V64.3A	Rzeszow	Poland	2001	100	1
GUD 1S. V94.3A	Seabank 2	U.K	2000	385	1
GUD 1S. V64.3A	Terni	Italy	2000	100	1
GUD 1S. V94.3A	Cottam	UK	1999	380	1
GUD 1S. V84.3A	Santa Rita	Philippine	1999	260	4
GUD 1S. V94.3A	Otahuhu	NZ	1998	260	1
GUD 1S. V84.3A	St. Fransis	USA	1998	260	2
GUD 1S. V94.3A	Quteiro	Portugal	1996	260	3
GUD 1S. V94.3	King's Lynn	U.K	1996	340	1
GUD 1S. V94.2	Buggenum	Netherlands	1993	280	1
TOTAL					26

Table I-4-7-19 3,000 rpm Multi-shaft Combined Cycle Power Experience (1/3)

Model	Plant Name	Country	Operation Year	Configuration	Unit Capacity(MW)	No. of Unit	Type of Fuel
ABB							
KA26-1	RDK Karlsruhe	DE	1997	1 on 1	360	1	NG/DO
KA26-2	Rocksavage	UK	1997	2 on 1	720	1	NG
KA26-2	Dock Sud	AR	2000	2 on 1	775	1	NG/DO
KA26-2	Coryton	UK	2001	2 on 1	775	1	NG/DO
KA26-1	Senoko	SG	2001	1 on 1	400	1	NG/DO
Total						***5***	
GE							
S209FA	Keadby	UK	1995	2 on 1	780	2	NG
S209FA	Little Barford	UK	1996	2 on 1	780	2	NG
S209FA	AES Medway	UK	1996	2 on 1	780	2	NG
S209FA	South Bangkok II	TH	1997	2 on 1	780	2	NG/DO
S109FA	Gent-Ringvaart	BE	1998	1 on 1	390	1	NG
S109FA	Nueva Renca	CL	1998	1 on 1	390	1	NG/DO
S109FA	Saint-Ghislain	BE	1999	1 on 1	390	1	NG
S209FA	Dabhol Power	IN	1999	2 on 1	780	2	NG/DO
S209FA	Rachaburi	TH	2000	2 on 1	780	1	NG/DO
S209FA	Tri Energy	TH	2000	2 on 1	780	2	NG/DO
S209FA	Sutton Bridge	UK	2000	2 on 1	780	2	NG
S209FA	Rachaburi	TH	2000	2 on 1	780	4	NG/DO
S109FA	Pulau Sakra	SG	2000	1 on 1	390	1	NG/DO
S109FA	Esch-Sur-Alzette	LX	2001	1 on 1	390	1	NG/DO
S209FA	Dabhol Power	IN	2001	2 on 1	780	4	NG/DO
S209FA	Castellon	SP	2001	2 on 1	780	2	NG/DO
Total						***30***	

Table I-4-7-19 3,000 rpm Multi-shaft Combined Cycle Power Experience (2/3)

Model	Plant Name	Country	Operation Year	Configuration	Unit Capacity(MW)	No. of Unit	Type of Fuel
MHI							
MPCP2(M701F)	EGAT Wang Noi I	TH	1997	2 on 1	650	2	NG/DO
MPCP2(M701F)	EGAT Wang Noi II	TH	1998	2 on 1	720	1	NG/DO
MPCP1(M701F)	San Isidro	CL	1998	1 on 1	370	1	NG/DO
MPCP2(M701F)	TEAS Bursa	TK	1999	2 on 1	700	2	NG
MPCP2(M701F)	Costanera	AR	1999	2 on 1	830	1	NG/DO
MPCP3(M701F)	Phu My I	VN	2001	3 on 1	1,090	1	NG/DO
MPCP2(M701F)	AES Parana	AR	2001	2 on 1	740	1	NG/DO
MPCP1(M701F)	AES Haripur	BAN	2001	1 on 1	360	1	NG
MPCP1(M701F)	PPN	IN	2001	1 on 1	360	1	NG/Naphtha
MPCP2(M701F)	Damhead	UK	2001	2 on 1	790	1	NG
MPCP2(M701F)	Port Dickson	ML	2004	2 on 1	730	1	NG/DO
MPCP2(M701F)	Cairo North	EGY	2004	2 on 1	750	1	NG/DO
Total						***14***	
Siemens							
GDU 1. 94.3A	Lujan De Cuyo	AR	1998	1 on 1	380	1	NG/DO
GDU 1. 94.3A	Nehuenco	CH	1998	1 on 1	380	1	NG/DO
GDU 2. 94.3A	Didcot	UK	1998	2 on 1	760	1	NG
GUD 2. 94.3A	Genelba	AR	1999	2 on 1	760	1	NG/DO
GUD 3. 94.3A	Al Taweelah	UAE	2000	3 on 1	1,155	2	NG/DO
GUD 3. 94.3A	Peterhead	UK	2000	3 on 1	1,155	1	NG
GUD 2. 94.3A	Seabank	UK	2000	2 on 1	770	1	NG
GUD 2. 94.3A	Salta	AR	2000	2 on 1	770	1	NG/DO
GUD 3. 94.3A	Al Taweelah	UAE	2001	3 on 1	1,155	2	NG/DO
GDU 1. 94.3A	Porto Marghera	IT	2001	1 on 1	385	1	NG
GDU 1. 94.3A	Verbrande Brug	BE	2001	1 on 1	385	1	NG

Table I-4-7-19 3,000 rpm Multi-shaft Combined Cycle Power Experience (3/3)

Model	Plant Name	Country	Operation Year	Configuration	Unit Capacity(MW)	No. of Unit	Type of Fuel
GDU 1. 94.3A	-	GR	2001	1 on 1	385	1	NG
GUD 3. 94.3A	Jebel Alik	UAE	2002	3 on 1	1155	2	NG/DO
GUD 1. 94.3A	La Casella	IT	2002	1 on 1	385	5	NG
GUD 1. 94.3A	Hunstown PWR Stat	IR	2002	1 on 1	385	1	NG
GUD 2. 94.3A	Teluk Gong	ML	2002	2 on 1	770	1	NG/DO
GUD 2. 94.3A	Phu My 3	VN	2003	2 on 1	770	1	NG/DO
GUD 2. 94.3A	Knapsack	GR	2004	2 on 1	770	1	NG
GUD 2. 94.3A	Rijnmond	NL	2004	2 on 1	770	1	NG
Total						***26***	

Table I-4-7-20 Application Experience with SSS Clutch over 100 MW for CCPPs

Site	Country	GT Type	Clutch MW	Plant MW
Kings Lynn	England	V94.3	150	1 × 338
Tapada do Quteiro	Portgal	V94.3A	150	3 × 330
Taranaki	New Zealand	GT26	152	1 × 325
Otahuhu	New Zealand	V94.3A	150	1 × 330
Santa Rita	Phillippines	V84.3A	100	4 × 220
St Francis	USA	V84.3A	100	2 × 220
Cottam	England	V94.3A	194	1 × 330
Monterry	Mexico	GT24	105	2 × 240
Agawan, MA	USA	GT24	105	1 × 240
Tocopilla	Chille	GT26	152	1 × 330
Enfield	England	GT26	152	1 × 330
Midlothian, TX	USA	GT24	105	4 × 240
Batam	Indinesia	V94.3A	150	1 × 330
Victoria, BC	Canada	GT24	105	1 × 338
Shoreham	England	GT26	152	1 × 330
Nanpu	Taiwan	M501F	91	1 × 251
Campeche	Mexico	M501F	101	1 × 282
Hunstown	Ireland	M701F	127	1 × 397
Morata	Spain	M701G	169	3 × 499
Sakaide	Japan	M501F	105	1 × 296

Table I-4-7-21 Computer Estimated Construction Costs for Multi-shaft CCPPs

Name of Components	Multi-shaft Arrangement without Bypass System				Multi-shaft Arrangement with Bypass System			
	Equipment	material	Labour	Total	Equipment	material	Labour	Total
Gas Turbine & Generator with Accessories	79,284	2,302	4,049	85,635	79,284	2,302	4,049	85,635
Steam Turbine & Generator with Accessories	35,393	2,842	4,020	42,255	35,393	2,842	4,020	42,255
Electrical Systems - Gas Turbine	5,446	139	592	6,177	5,446	139	592	6,177
Condensate Heating System	2,410	9	441	2,860	2,411	9	441	2,861
HRSG & Accessories	29,456	681	7,416	37,553	29,457	681	7,417	37,555
Deaeration System	263	104	337	704	263	104	337	704
Steam Piping	0	596	626	1,222	0	596	626	1,222
Electrical Systems - HRSG	73	130	367	570	73	130	367	570
Steam Bypass System	1,837	44	317	2,198	1,837	44	317	2,198
Electrical Systems - Steam Turbine	5,474	2,133	1,760	9,367	5,475	2,133	1,760	9,368
Condenser & Accessories	4,837	92	703	5,632	4,837	92	703	5,632
Circulating Water System	5,407	7,394	4,077	16,878	5,409	7,396	4,078	16,883
Water Treatment System	1,938	798	1,084	3,820	1,938	798	1,084	3,820
Waste Water Treatment System	1,241	67	548	1,856	1,241	67	548	1,856
Boiler Feed System	624	104	285	1,013	624	104	285	1,013
Condensate System	127	93	193	413	127	93	193	413
Buildings	1,547	22,753	11,971	36,271	1,547	22,747	11,968	36,262
Fire Protection System	1,328	58	1,066	2,452	1,328	58	1,066	2,452
Fuel Systems	2,343	643	1,170	4,156	2,343	643	1,170	4,156
Fuel Gas Compressor & Accessories	7,210	1,765	740	9,715	7,210	1,765	740	9,715
Bypass Stack & Diverter Valve	-	-	-	-	2,813	155	1,306	4,274
Main Exhaust Stack	0	1,049	497	1,546	0	1,049	497	1,546
Station & Instrument Air System	571	418	266	1,255	571	418	266	1,255
Closed Cooling Water System	487	255	275	1,017	486	255	275	1,016
Cranes & Hoists	204	239	215	658	204	239	215	658
Plant Control System	1,906	0	176	2,082	1,906	0	176	2,082
Continuous Emission Monitoring System	377	251	464	1,092	754	503	928	2,185
Total Process Capital	189,783	44,959	43,655	278,397	192,977	45,362	45,424	283,763

Unit 1,000 US$

Table I-4-7-22 Computer Estimated Construction Costs for Single-shaft CCPPs

Name of Components	Single-shaft Arrangement without SSS Clutch				Single-shaft Arrangement with Clutch and Bypass System			
	Equipment	material	Labour	Total	Equipment	material	Labour	Total
Gas Turbine & Accessories	59,906	2,302	4,049	66,257	59,906	2,302	4,049	66,257
Generator & Accessories - Gas Turbine	43,682	2,841	4,476	50,999	44,095	2,842	4,482	51,419
Electrical Systems - Gas Turbine	2,859	139	592	3,590	2,859	139	592	3,590
Condensate Heating System	2,410	9	441	2,860	2,411	9	441	2,861
HRSG & Accessories	29,456	681	7,416	37,553	29,457	681	7,417	37,555
Deaeration System	263	104	337	704	263	104	337	704
Steam Piping	0	596	626	1,222	0	596	626	1,222
Electrical Systems - HRSG	73	130	367	570	73	130	367	570
Steam Bypass System	1,837	44	317	2,198	1,837	44	317	2,198
Electrical Systems - Steam Turbine	7,614	2,133	1,760	11,507	7,615	2,133	1,760	11,508
Condenser & Accessories	4,837	92	703	5,632	4,837	92	703	5,632
Circulating Water System	5,407	7,394	4,077	16,878	5,409	7,396	4,078	16,883
Water Treatment System	1,938	798	1,084	3,820	1,938	798	1,084	3,820
Waste Water Treatment System	1,241	67	548	1,856	1,241	67	548	1,856
Boiler Feed System	624	104	285	1,013	624	104	285	1,013
Condensate System	127	93	193	413	127	93	193	413
Buildings	1,547	22,753	11,971	36,271	1,547	22,747	11,968	36,262
Fire Protection System	1,328	58	1,066	2,452	1,328	58	1,066	2,452
Fuel Systems	2,343	643	1,170	4,156	2,343	643	1,170	4,156
Fuel Gas Compressor & Accessories	7,210	1,765	740	9,715	7,210	1,765	740	9,715
Bypass Stack & Diverter Valve	-	-	-	-	2,813	155	1,306	4,274
Main Exhaust Stack	0	1,049	497	1,546	0	1,049	497	1,546
Station & Instrument Air System	571	418	266	1,255	571	418	266	1,255
Closed Cooling Water System	487	255	275	1,017	486	255	275	1,016
Cranes & Hoists	204	239	215	658	204	239	215	658
Plant Control System	1,906	0	176	2,082	1,906	0	176	2,082
Continuous Emission Monitoring System	377	251	464	1,092	754	503	928	2,185
Total Process Capital	178,247	44,958	44,111	267,316	181,854	45,362	45,886	273,102

Unit 1,000 US$

4.7.4 Selection of Cooling System

The study on the selection of cooling system for the steam turbine condenser of this power plant was carried out with the following steps.

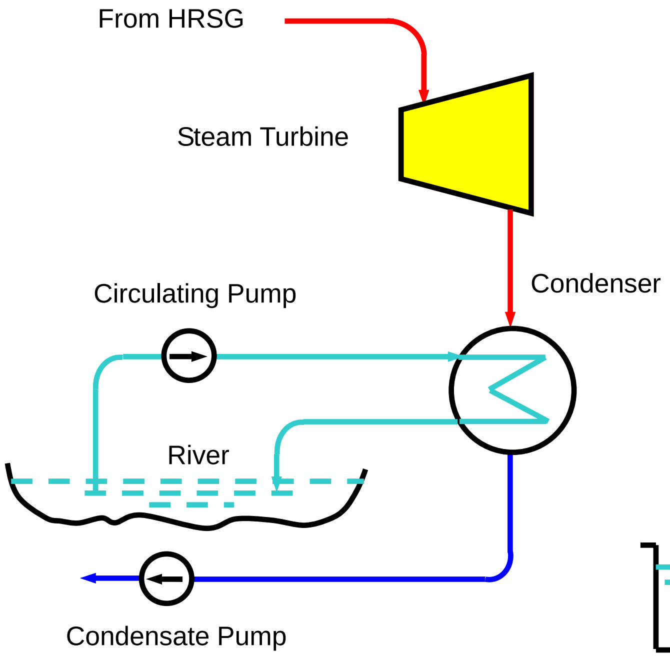
Step 1: Comparison study on the cooling system
Step 2: Comparison study on the intake system of cooling water
Step 3: Selection of the cooling system

In the step 1, three (3) types of cooling systems to be considered for this plant were studied from technical and economic points of view including the impact on environments.
In the step 2, the intake systems for the two (2) types of cooling systems where cooling or make-up water is required out of three (3) types were studied. As for the make-up water, the following two (2) types of methods were performed from the technical possibility point of view including the impact on environments.
In the step 3, the condenser cooling system optimal to this plant was chosen based on the study results of steps 1 and 2.

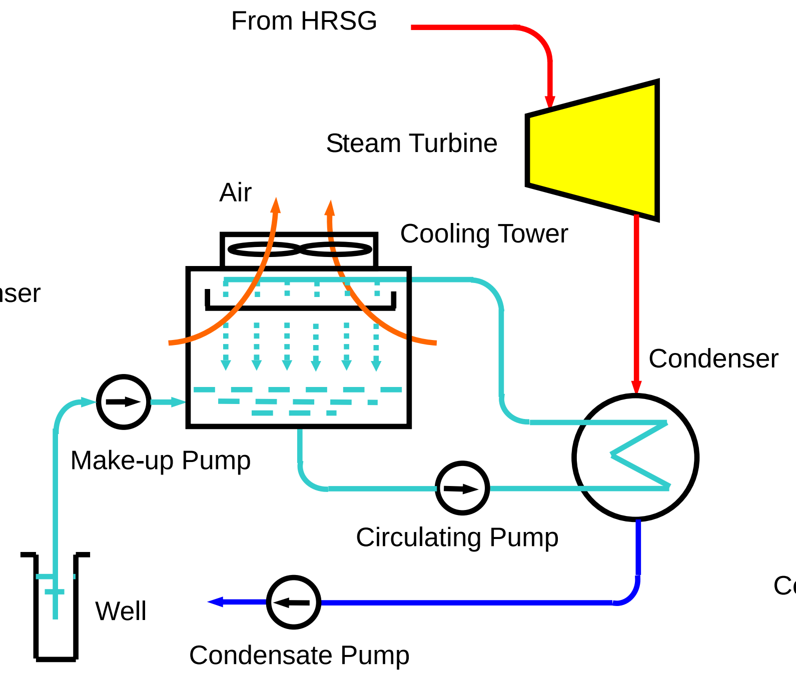
(1) Comparison Study of Condenser Cooling Systems

1) General

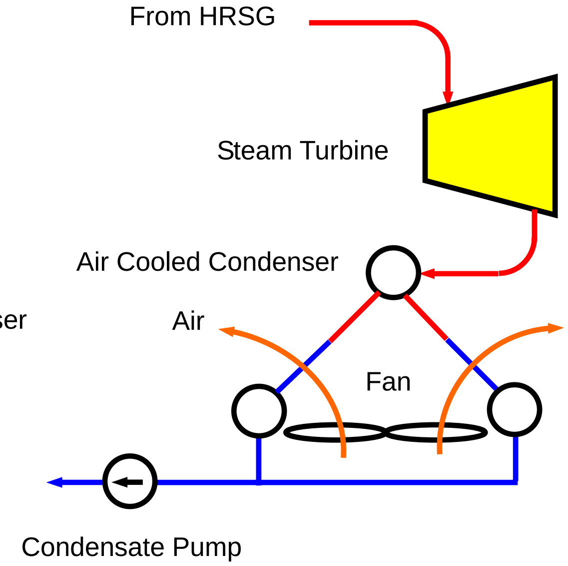
Three (3) types of cooling systems of a once-through cooling system, a forced draft cooling tower system and a forced draft air cooling system could be considered as the cooling system of the steam turbine condenser for the Project. The merits and demerits of the cooling system are variable depending upon the site ambient conditions, operating conditions and economic conditions such as an electric power sales price and a fuel cost. This study is carried out from technical and economical points of view for selection of the most suitable cooling system for the Project. The impact on circumferential environments is also examined. Other two (2) types of cooling systems of natural draft cooling tower and air cooling systems are precluded from the possibility of study because a huge area is necessary for installation of equipment.
The schematic diagram of the three (3) types of cooling systems is shown in the page to be continued hereinafter.
In the combined cycle power plant, the performances of the gas turbine which is a topping cycle are not affected with the type of cooling system, but those of the steam turbine of a bottoming cycle are affected. Therefore, it is effective enough for technical and economic evaluation if the performance differences due to the type of cooling system of only the steam turbine are examined.



Once-through Cooling System



Forced Draft Cooling Tower System



Forced Draft Air Cooling System

Schematic Diagram of Cooling System

2) Conditions

a. Type of Combined Cycle Power Plant

This study shall be conducted for the combined cycle power plant (CCPP) which uses the F-class gas turbine presently available in the worldwide market. Out of four (4) Models of CCPPs, MPCP1(M701F) is used as the case for selection study of the cooling system because its nominal capacity is the largest out of them. As for the parameters of the bottoming system, the sub-section 5.5.3 should be referred to.

b. Site Ambient Conditions

The heat load of the cooling system of the CCPP is significantly changeable depending upon the ambient conditions. Therefore, the study shall be performed at the averaged ambient conditions through the year. For the purpose, the averaged site ambient conditions are obtained from the site survey results. These data are obtained as averaged figures through the year 2002 to 2007 at the place of Ishudri which is located at the northern part of the Bheramara Site. Their specific figures are as tabled below:

Averaged dry bulb temperature	25.2 ^{o}C
Averaged relative humidity	78.3 %
Averaged wet bulb temperature	23.7 ^{o}C
Averaged river water temperature	21.0 ^{o}C

The averaged river water temperature is assumed to be 21.0^{o}C for selection study of the cooling system.

c. Operating Conditions

The study is conducted provided that the plant is scheduled to be run at a full load on a natural gas with an annual availability factor of 70% through the period.

d. Economic Conditions

The economic evaluation of the cooling system is conducted comparing the construction cost for the condenser and cooling system plus the loaded cost as the net present value due to the shortage of the annual power sales of the steam turbine among the three (3) types of cooling systems. For the purpose, the following economic indexes are utilized:

Electricity tariff	0.032 $/kW/hr
Escalation rate of Electricity tariff	1.5 %
Discount rate	10.0 %
System loss	8.0 %
Evaluation periods (year)	25.0 years
Construction period (year)	3.0 years

3) Shortage of Annual Net Sales Power (GWh) due to Type of Cooling System

The steam turbine gross power output at the generator terminals can be obtained from the heat balance calculation result for estimating the steam turbine exhaust pressure which will be defined at the used energy end point (UEEP) of the steam turbine. The said pressure will be determined for each type of cooling system on specified site ambient conditions. It is normally deemed that the said pressure is equal to the condenser pressure except for the air-cooled condenser. In case of the air-cooled condenser, the pressure loss will happen to the steam duct between the steam turbine and the air-cooled condenser. The net power output at the power station is defined as the value after the auxiliary powers related to the cooling system are deducted from the gross power output. The annual net sales power is estimated multiplying the net power output by the annual operating hours and deducting the system power loss. The shortage of the annual net power is defined as the difference between the maximum net and annual net power sales.

a. Estimation of pressure

The pressure at UEEP can be estimated from the commonly acceptable characteristic values for each type of cooling system on the site ambient conditions specified above. The estimated pressures for each cooling system are as tabulated in the table shown below:

Description	Temperature and Pressure
1. Once-through cooling system	
a. Temperature rise (°C)	8.0
b. Temperature difference (°C)	5.0
c. Condenser saturated temp. (°C)	= 21.0+8.0+5.0 = 34.0
d. Condenser saturated pressure (kPa)	5.32
e. Estimated pressure loss (kPa)	0
f. Estimated pressure at UEEP (kPa)	5.32
2. Forced draft cooling tower system	
a. Approach temperature (°C)	8.0
b. Cooling range (°C)	8.0
c. Temperature difference (°C)	5.0
d. Condenser saturated temp. (°C)	=23.7+8.0+8.0+5.0 =44.7
e. Condenser saturated pressure (kPa)	9.43
f. Estimated pressure loss (kPa)	0
g. Estimated pressure at UEEP (kPa)	9.43
3. Forced draft air cooling system	
a. Air temperature rise (°C)	12.0
b. Temperature difference (°C)	8.0
c. Condenser saturated temp. (°C)	=25.2+12.0+8.0 =45.2
d. Condenser saturated pressure (kPa)	9.68
e. Estimated pressure loss (kPa)	10.00
f. Estimated pressure at UEEP (kPa)	19.68

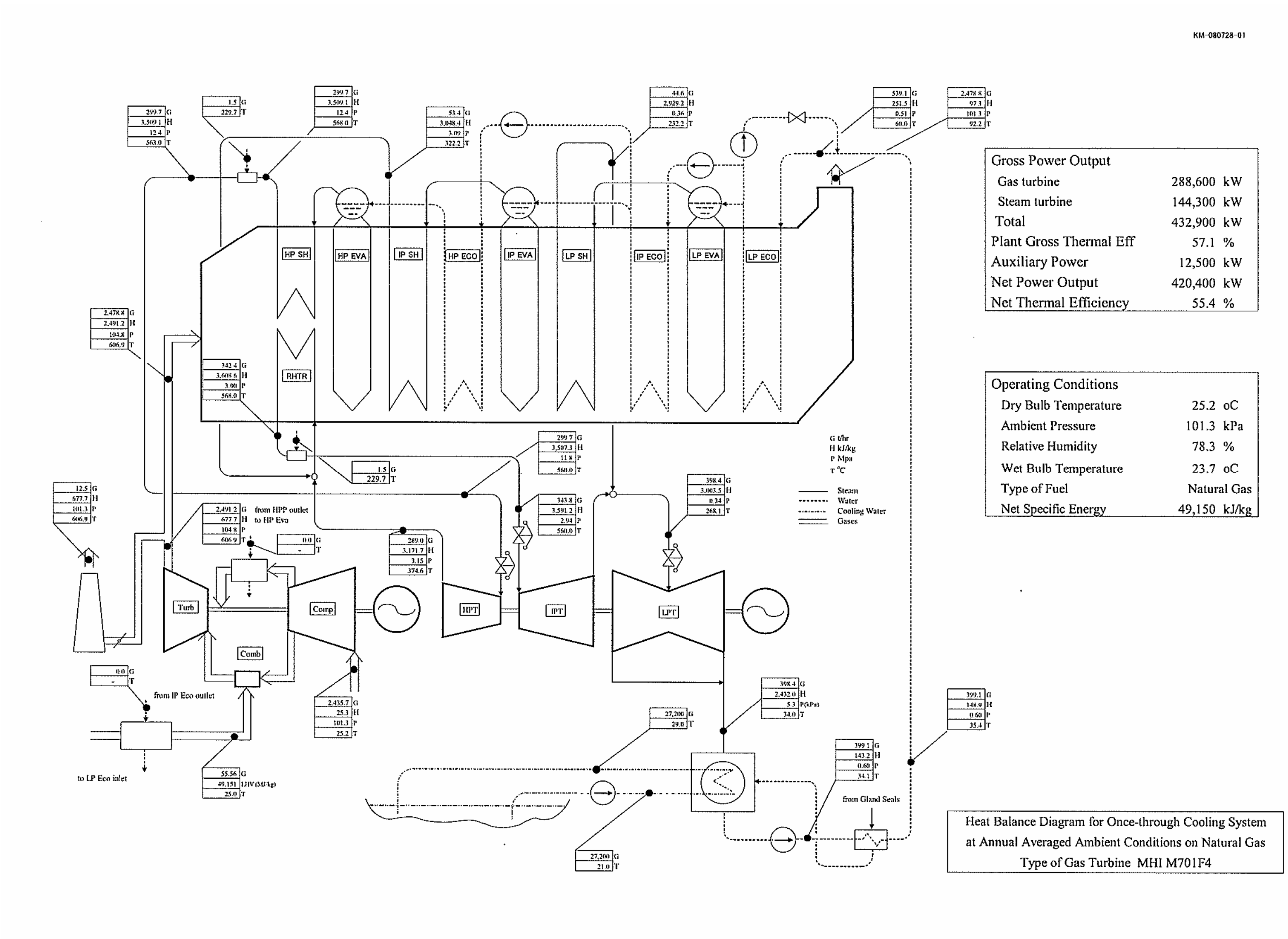
b. Gross power output of steam turbine

The gross power outputs of the steam turbine for three (3) types of cooling systems can be obtained from the heat balance calculation results for the specified exhaust pressures at UEEP. They are as tabled below:

Type of Cooling System	Gross Power Output (kW)
Once-through cooling system	144,300
Forced draft cooling tower system	138,900
Forced draft air cooling system	132,100

The following heat balance diagrams for three (3) types of cooling systems are shown in the pages to be continued.

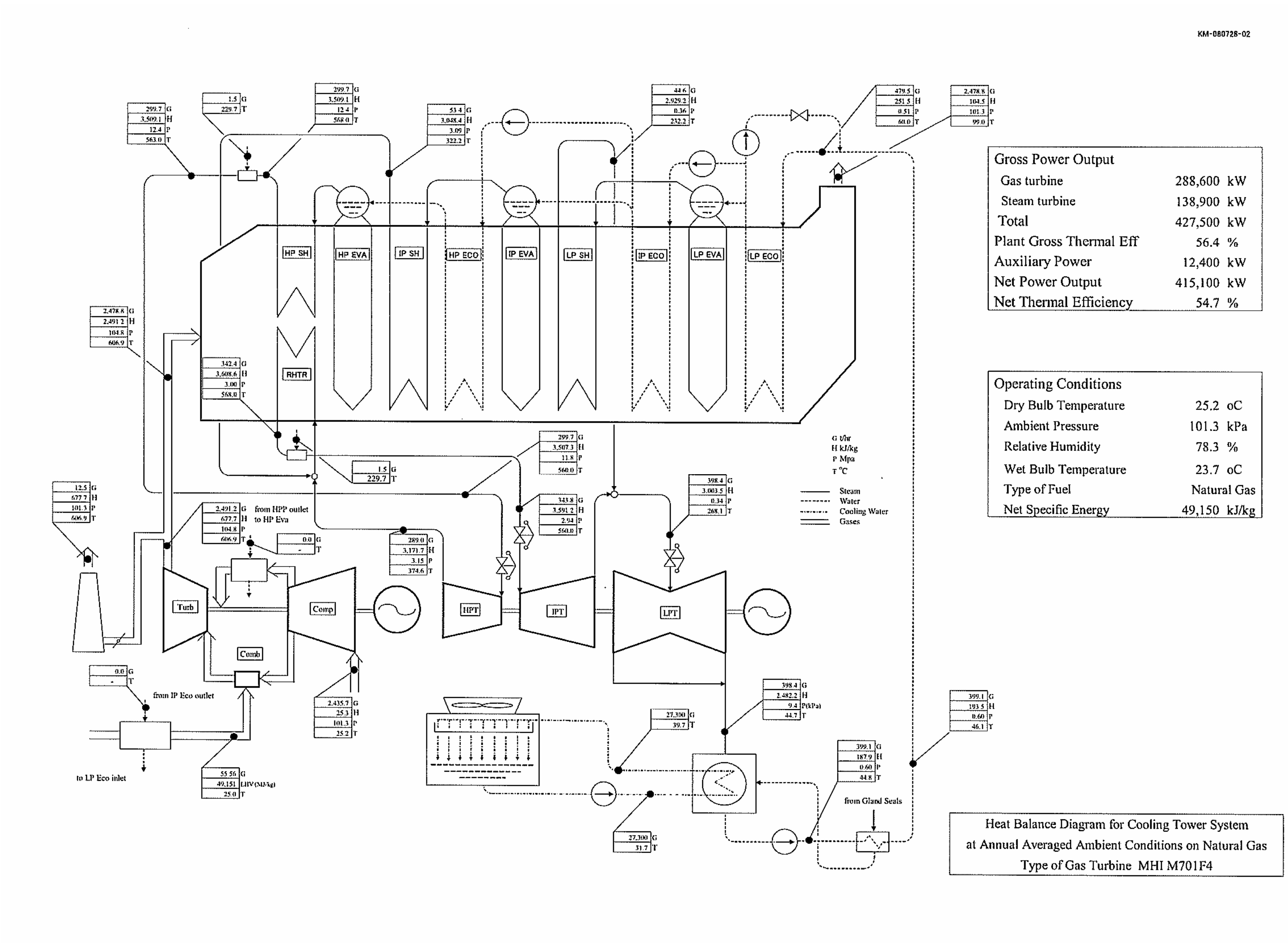
a) Heat Balance Diagram for Once-through Cooling System
b) Heat Balance Diagram for Forced Draft Cooling Tower System
c) Heat Balance Diagram for Forced Draft Air Cooling System

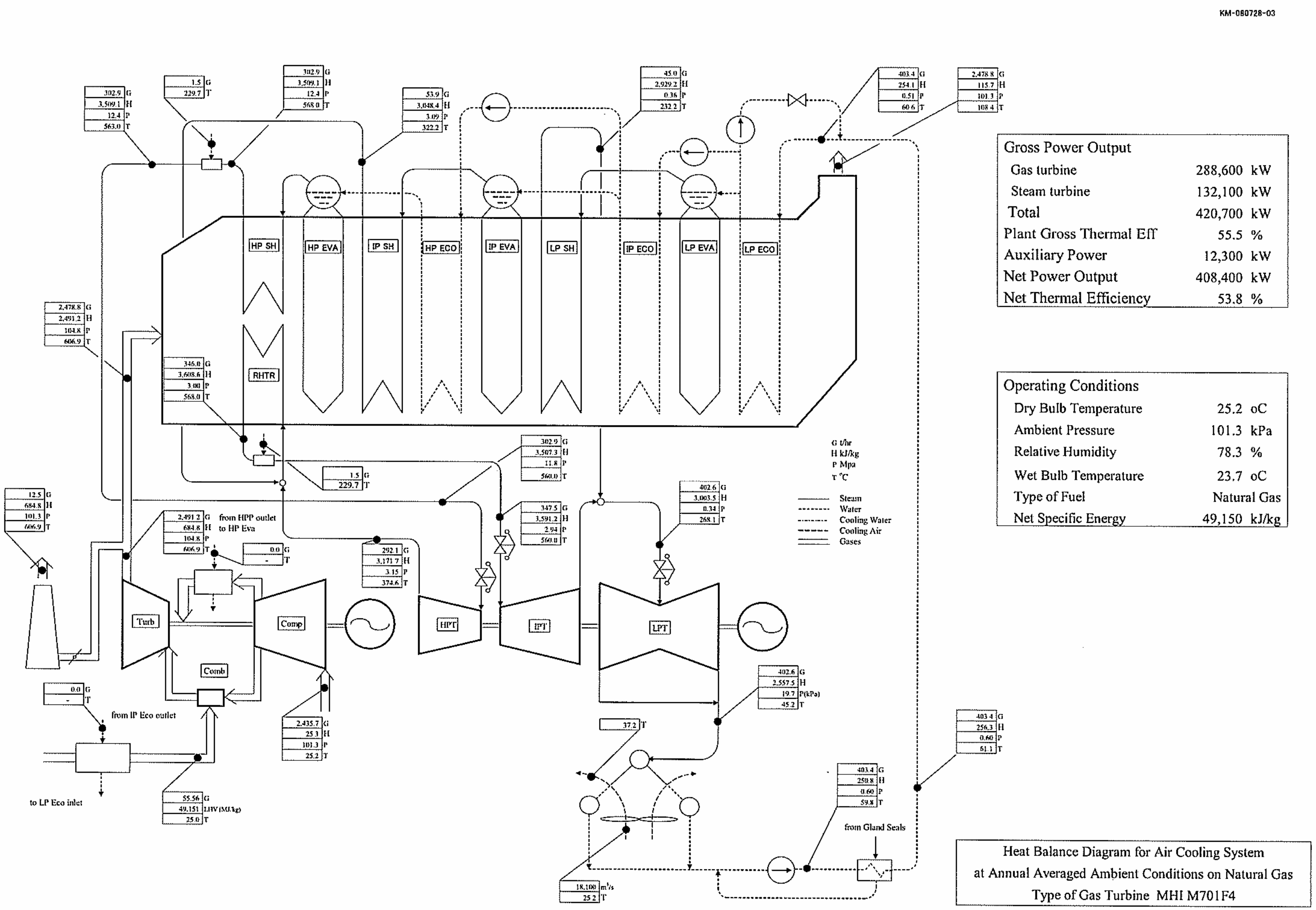


Gross Power Output		
Gas turbine	288,600	kW
Steam turbine	144,300	kW
Total	432,900	kW
Plant Gross Thermal Eff	57.1	%
Auxiliary Power	12,500	kW
Net Power Output	420,400	kW
Net Thermal Efficiency	55.4	%

Operating Conditions		
Dry Bulb Temperature	25.2	oC
Ambient Pressure	101.3	kPa
Relative Humidity	78.3	%
Wet Bulb Temperature	23.7	oC
Type of Fuel	Natural Gas	
Net Specific Energy	49,150	kJ/kg

Heat Balance Diagram for Once-through Cooling System at Annual Averaged Ambient Conditions on Natural Gas Type of Gas Turbine MHI M701F4


KM-080728-02
Gross Power Output
Gas turbine 288,600 kW
Steam turbine 138,900 kW
Total 427,500 kW
Plant Gross Thermal Eff 56.4 %
Auxiliary Power 12,400 kW
Net Power Output 415,100 kW
Net Thermal Efficiency 54.7 %
Operating Conditions
Dry Bulb Temperature 25.2 oC
Ambient Pressure 101.3 kPa
Relative Humidity 78.3 %
Wet Bulb Temperature 23.7 oC
Type of Fuel Natural Gas
Net Specific Energy 49,150 kJ/kg
HP SH
HP EVA
IP SH
HP ECO
IP EVA
LP SH
IP ECO
LP EVA
LP ECO
RHTR
Turb
Comp
Comb
HPT
IPT
LPT
G t/hr
H kJ/kg
P Mpa
T °C
Steam
Water
Cooling Water
Gases
from HPP outlet to HP Eva
from IP Eco outlet
to LP Eco inlet
from Gland Seals
Heat Balance Diagram for Cooling Tower System
at Annual Averaged Ambient Conditions on Natural Gas
Type of Gas Turbine MHI M701F4



Gross Power Output		
Gas turbine	288,600	kW
Steam turbine	132,100	kW
Total	420,700	kW
Plant Gross Thermal Eff	55.5	%
Auxiliary Power	12,300	kW
Net Power Output	408,400	kW
Net Thermal Efficiency	53.8	%

Operating Conditions		
Dry Bulb Temperature	25.2	oC
Ambient Pressure	101.3	kPa
Relative Humidity	78.3	%
Wet Bulb Temperature	23.7	oC
Type of Fuel	Natural Gas	
Net Specific Energy	49,150	kJ/kg

Heat Balance Diagram for Air Cooling System
at Annual Averaged Ambient Conditions on Natural Gas
Type of Gas Turbine MHI M701F4

c. Auxiliary power related to cooling system

The auxiliary power of the equipment pertaining to the cooling system is different depending upon its type. The auxiliary powers for the foresaid three (3) types of cooling systems are roughly estimated by correcting the relevant data of similar plants to the site conditions of this Project. The study results are summarized as described below.

Once-through cooling system	
Cooling water circulating pump (Q=28,700 m^3/hr, H=25 m)	2,900 kW
Screen wash pump (Q=150 m^3/hr, H=70 m)	40 kW
Total	2,940 kW

Forced draft cooling tower system	
Cooling water circulating pump (Q=28,800 m^3/hr, H=18 m)	1,750 kW
Draft fan in total (Q=4,700 m^3/s, H=12 mmH_2O)	750 kW
Make-up water supply pump (Q=1,150 m^3/hr, H=50 m)	230 kW
Total	2,730 kW

Forced draft air cooling system	
Draft fan for condenser in total (Q=18,000 m^3/s, H=13 mmH_2O)	3,400 kW
Draft fan for equipment in total (Q=530 m^3/s, H=15 mmH_2O)	150 kW
Total	3,550 kW

d. Net power output

From the gross power outputs and auxiliary powers estimated above, the net power outputs are calculated as shown below:

Type of Cooling System	Net Power Output (kW)
Once-through cooling system	141,360
Forced draft cooling tower system	136,170
Forced draft air cooling system	128,550

e. Annual net sales power

The annual net sales power for three (3) types of cooling systems are estimated as shown below in consideration of net power output, annual availability factor and system loss.

Type of Cooling System	Annual Net Sales Power (GWh)
Once-through cooling system	797.5
Forced draft cooling tower system	768.2
Forced draft air cooling system	725.2

f. Shortage of annual net sales power

In accordance with the previously prescribed definition, the shortage of annual net sales power for each cooling system is calculated as shown below:

Type of Cooling System	Shortage of Annual Net Sales Power (GWh)
Once-through cooling system	± 0
Forced draft cooling tower system	29.3
Forced draft air cooling system	43.0

4) Technical Evaluation

a. Once-through cooling system

This system is the most common system to various kinds of power generation plants. The condenser vacuum is estimated at 5.32 kPa considering the temperature rise across the condenser of 8 ^{o}C for the river water temperature of 21 ^{o}C as shown in the previous page. As the results, the steam turbine net power output could be largest among three (3) types of cooling systems. That means that the plant thermal efficiency is highest among them.

However, there must be any available cooling water source from which the necessary amount (some 30,000 m^3/hr including that for equipment lube oil systems) of water with suitable quality could be stably taken into the condenser and be discharged to the water source. In case of this Project, Padma River could be considered as the water source since it is located comparably close to the candidate site of the Plant.

The routing of the intake and discharge channels and type of them between the river and the site shall be decided at the detailed design stage and a huge amount of civil works shall be required. During civil works for construction of the intake and discharge channels, significant consideration of impact on circumferential environments shall be specially paid from viewpoints of dust, noise, vibration etc.

In case of this system, the thermal effluent of as much as 30,000 m^3/hr shall be discharged to Padma River. The river temperature rise due to the thermal effluent may give any influent on the River.

As mentioned in the successive sub-section (2) [Study on Water Intake of Cooling Systems], however, it was founded that it was impossible to steadily intake the necessary amount of cooling water from the River. Therefore, specific studies about impacts on environments due to civil works and river temperature rise were not conducted.

b. Forced draft cooling tower system

This system is also common to the power generation plants to be built in the area where the water source with necessary amount of flow rate capacity is not available. The re-circulating cooling water flow rate of the cooling tower is estimated to be some 30,000 m^3/hr including the cooling water for equipment.

As described in the previous section, the net power output of the steam turbine is large next to the once-through type cooling system.

In case of use of this type of cooling tower, some 4% of the re-circulating water flow rate must be made up to compensate the blow-down water and evaporation and water drift losses depending upon the design parameters of the tower. The blow-down water flow rate is assumed some 2 % to keep the solid concentration in the circulating water within 2 times that in the make-up water. The remaining 2% is required for compensation of evaporation and water drift losses. Therefore, the required make-up water flow rate can be calculated at 1,200 m^3/hr.

Depending upon the quality of the make-up water and the contamination of ambient air, any kinds of slime and algae may occur in the system and the tower fills may be scaled. Therefore, any measures by dosing of suitable chemicals must be taken to protect this system from them. However, these matters shall be engineered at the detailed design stage of the project in consideration of types of chemicals which will be locally available.

According to preliminary study results, the cooling tower is configured of five (5) cells of which each is sized at approximately 12 m in length, 13 m in width and 18 m in height with a fan of 9 m in diameter. The total footprint area is approximately 15 m by 65 m. This type of cooling tower is technically matured and many installation experiences exist for various types of power plants.

As previously mentioned, any make-up water is necessary for this system. As the site survey results of the successive sub-section (2) [Study on Water Intake of Cooling Systems], the underground water is to be used as the make-up water. In this case, any influence on the circumferential environments due to pumping-up of the water (1,300 m^3/hr) will be concerned. For study of the influence, the site survey including the pumping-up test using the test wells was conducted. The details of the site survey results are described in the sub-section 4.6.5 [Water Source]. As the results, it was confirmed that the pumping-up of the underground water for the long term through the plant lifetime would not give rise to any significant influence on circumferential environments.

As previously mentioned, some 2% (600 m^3/hr) of the circulating water must be continuously blown down to the River. The water blown down from the cooling tower water reserve vessel is discharged to the Padoma River via a culvert (500 m). Any dusts (sand, soil, ash, carbon, fiber and etc.) floating in the ambient air may be mixed with the circulating water. Therefore, the blown water will be discharged into the River after proper mesh type filtration treatment. The temperature of the blown water (thermal effluent water) is designed at 39.8^oC, which meets the regulation of 40^oC of the Bangladesh. The flow rate of the blown water is approximately 0.025% times the minimum river water (30^oC) flow rate at the dry season. Therefore, it is definitely envisaged that any influence on the environments by the blown water. Besides, the detailed study (temperature profile simulation analysis) will be carried out at the detailed design stage of the Project and any countermeasures (design change, water discharge method) to mitigate the influence will be taken as per required.

The mechanical sounds from the axial air fans and water circulating pumps and dripping sounds of water drops could be supposed as noise sources of this system. The sounds from the axial air fans can be attenuated by employment of low noise type of fans and cylindrical hood at the air exit. The circulating pumps could be covered with the noise attenuation enclosure for reduction of noise. The dripping sounds could be protected by installation of the air inlet louvers. By such noise protection measures as described above, the sound pressure levels around the cooling tower could be suppressed less than 85 dB(A).

As the noise simulation analysis results (the detail of analysis results in the sub-section 7.3.2 (2) 4) to be referred) based on noise data of the main equipment consisting of the plant, the sound pressure levels on the border of the power station was found to be less than the prescribed value.

c. Forced draft air cooling system

This type of system has been used for the power generation plants which are built in areas where water sources are not available in the vicinity of plants as inland and desert areas. The steam from the steam turbine is directly condensed by ambient air through the finned tubes. For the purpose, huge amount of surface area is required for the heat transfer finned tubes because of less heat transfer coefficient between the air and steam.

As described in the previous section, the net power output of the steam turbine will be the lowest among three (3) types of cooling systems.

The finned tubes are kept to be clean by employment of automatic water wash devices which will be periodically operated depending upon the fouling tendency of them. The site for this Plant belongs to clean area not contaminated different from industrial areas. It is supposed for the finned tubes to be less contaminant. The air leakage into tubes could be detected by use of an infrared camera. The finned tubes where the leakage will be detected could be blinded with plugs for further use of the system.

According to study results, the air cooling system is configured of twenty (20) cells in total. Each cell is approximately sized at 14 m by 15 m with a fan of 12 m in diameter of

170 kW power requirements. The totally required footprint area for installation of the air cooling system is approximately 60 m by 75 m. The height is some 20 m. Depending upon the shape of the given installation area, the area of 30 m by 150 m is available.

The steam turbine building height could be lowered because the steam turbine will be installed on the ground level. The steam turbine exhaust is preferably of axial flow type and connected with the condenser by pipe.

The forced draft air cooling system is technically matured and there are many installation experiences with such large capacity systems as required for this Plant as shown in the Table I-4-7-22. This table shows the sample of worldwide reference of one (1) major of air cooling system manufacturer for steam turbines with more capacity than 150 MW.

The mechanical sounds from the axial air fans are supposed to be the noise source of this cooling system. It is possible that the sound pressure levels around the system will be allowable from the environmental consideration point of view by employment of lower noise fans and installation of noise protection louvers at the air inlet.

For example, it is confirmed that the noise levels on the ground level around the similar cooling system located in Japan are less than 85 dB(A).

As the noise simulation analysis results in accordance with the noise data of the main equipment consisting of the plant, the sound pressure levels on the border of the power station was found to be less than the prescribed value.

5) Economic Evaluation

a. Loaded cost due to shortage of annual net sales power

The loaded cost is defined to be equal to the net present value (NPV) due to the shortage of the annual net sales power by the steam turbine with a certain cooling system against the steam turbine with the maximum annual net sales power. Therefore, the NPV can be calculated with the following formula. In this case study, the maximum annual net sales power is 797.5 GWh of the steam turbine with the once-through type cooling system as shown in the sub-section 4.7.4(1).

$$NPV=(1+ER/100)^{P}/(1+DR/100)^{P}\times(1+ER/100)\times((1+DR/100)^{S}-(1+ER/100)^{S})/(DR/100-ER/100)/(1+ER/100)^{S}\times PSP\times(797.5-APG)\times(1-SL/100) \quad (MUS\$)$$

Where,

ES:	Escalation rate of power sales tariff (%)
DR:	Discount rate (%)
P:	Period of construction (year)
S:	Service period (year)
PSP:	Power sales tariff (US$/kWh)
APG:	Annual sales (GWh) of power generation by steam turbine for individual cooling system
SL:	Transmission and Distribution System Loss (%)
797.5:	Annual net sales power (GWh) of the steam turbine with once-through type cooling system

Substituting the said preconditioned values in sub-section 4.7.4 (1) and annual net sales power by the steam turbine for the individual cooling system into the above equation, the loaded costs for the individual cooling system are calculated as shown below:

Type of Cooling System	Loaded Cost (MUS$)
Once-through cooling system	±0.0

Forced draft cooling tower system + 7.6
Forced draft air cooling system + 11.2

As shown by above figures, the loaded costs for the cooling tower and air cooling systems are higher compared with those of the once-through type system. These large differences are derived from the differences of condenser vacuum pressure of the steam turbine depending upon the type of the cooling system.

b. Construction cost for condenser and cooling system

The construction cost for individual cooling system is estimated through the computer software referring the relevant cost of similar project. The closed component cooling system is not included in the estimation of the construction cost because its specification is deemed to be common to all types of cooling systems.

The costs of any civil works associated with the intake and discharge channels for once-through cooling system are tentatively estimated from the experience with similar plants for comparison of the cooling system.

The costs for the ground water pump-up system including boring cost of the well for make-up water of the cooling tower system are also tentatively imagined from the experience with similar plants for comparison of the cooling system.

The estimated costs are summarized as shown below:

MM US$

Description	Once-through	Cooling Tower	Air-cooled
Condenser and accessories	5.5	6.2	-
Circulating Water System	9.5	17.4	-
Cooling Tower	-		-
Air-cooled Condenser	-	-	31.7
Intake & Discharge Channel Civil works (assumed)	15.0	-	-
Groundwater Pump-up System including well drilling	-	1.0	-
Total	30.0	24.6	31.7

As shown in this table, the construction cost of the forced draft air cooling system is highest among the three (3) types of cooling systems.

c. Construction cost plus loaded cost

The construction cost plus loaded cost for three (3) types of cooling systems are as tabulated below from values estimated above.

Type of Cooling System	Construction and Loaded Costs (MUS$)
Once-through cooling system	30.0
Forced draft cooling tower system	32.2
Forced draft air cooling system	42.9

As can be seen from above figures, the difference of economy between the once-through cooling and forced draft cooling tower systems is very small, while the forced draft air cooling system is more uneconomic compared with any other two (2) types of cooling systems.

Table I-4-7-23 Sample of Application Experiences with Air Cooled Condenser for Steam Turbines above 150 MW

Custmer	Project Name	Country	Turbine Capacity (MW)	Ambient Air Temp	Costruction Year
State Power	Datong No.2	China	2 × 600	30.0	2004
ACS/Sener	Amorebieta	Spain	285	15.0	2004
Edison	Altmonte	Italy	250	15.0	2004
Edison	Candela	Italy	380	15.0	2003-2004
Intergen	Sparkling Energy	Great Britain	358	9.4	2003
Calpine	Otay Mesa	USA	277	23.3	2003
State Power	Datong No.1	China	160	16.0	2003
Siemens	Kuo Kuang	Taiwan	160	32.0	2002
Reliant Energy	Choctaw County	USA	350	32.2	2002
Reliant Energy	Hunterstown	USA	350	32.2	2002
Duku Energy Moapa LLC	Moapa	USA	2 × 250	39.4	2002
Front Range Power	Front Range	USA	150	26.7	2001
Intergen	Coryton Energy	Great Britain	250	10.0	2001
Intergen	Bajio	Mexico	150	21.9	2000
Intergen/Shell Coal	Millmeran	Auatralia	2 × 420	31.1	2000
Sempra Energy	El Dorado	USA	150	19.4	1999
Pluspentrol Energy S. A	Tucuman	Argentina	150	37.2	1997
Comison Federal de Electricidad	Samalayuca II	Mexico	210	37.2	1996
Tavanir/Siemens	Gilan	Iran	3 × 390	33.0	1991-1994
ESCOM	Majuba	South Africa	3 × 665	14.0	1990-1992
ESCOM	Matimba	South Africa	6 × 665	23.0	1985-1991
CEEE, Porto Allegre	Candiota	Brasil	2 × 160	20.0	1982-1983
Black Hills Power/Pasic Power	Wyodak	USA	330	18.9	1977
HKG Hamm Uentrop	KKW Schmehausen	Germany	330	12.0	1974
Siemens/Union Temica S.A	Utrillas	Span	160	15.0	1968
Preussag	KW ibbeenburen	Germany	150	1.5	1964-1967

(2) Study on Water Intake for Cooling Systems

1) Once-through cooling system

Cooling water of approximately 40,000m^3/hr should be required for once-through cooling system. Following two (2) types of water intake could therefore be considered for taking the above huge amount of water directly from Padma River.

・Open Cut
・Intake Tower

a. Open Cut

Water intake directly through open channel cut on the bank of Padma River
Conceptual drawing of open cut is shown in the Figure I-4-7-5.

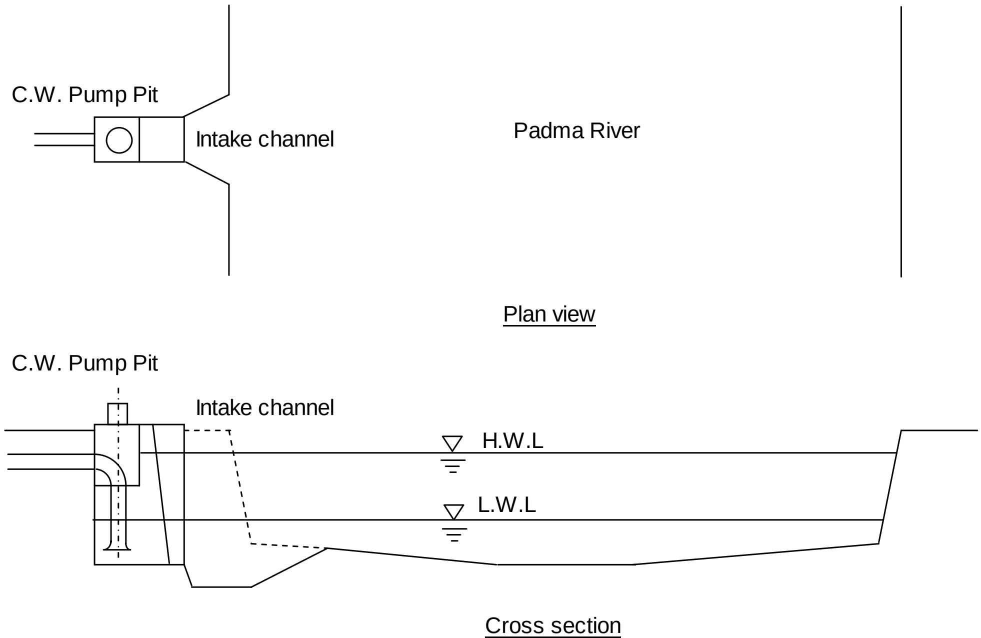


Figure I-4-7-5 Open Cut

Based on the survey data as mentioned in Section 4.6.5 Water source (1) Hydrological and morphological data of Padma River, it is concluded that water intake by open cut is impossible during dry (low-water) season due to the following reasons;

・heavy sand sedimentation along the right bank of the River
・top level of sedimentation is higher than the water level of the River

b. Intake Tower

Water intake through intake tower/pipe set in the middle of Padma River
Conceptual drawing of open cut is shown in the Figure I-4-7-6.

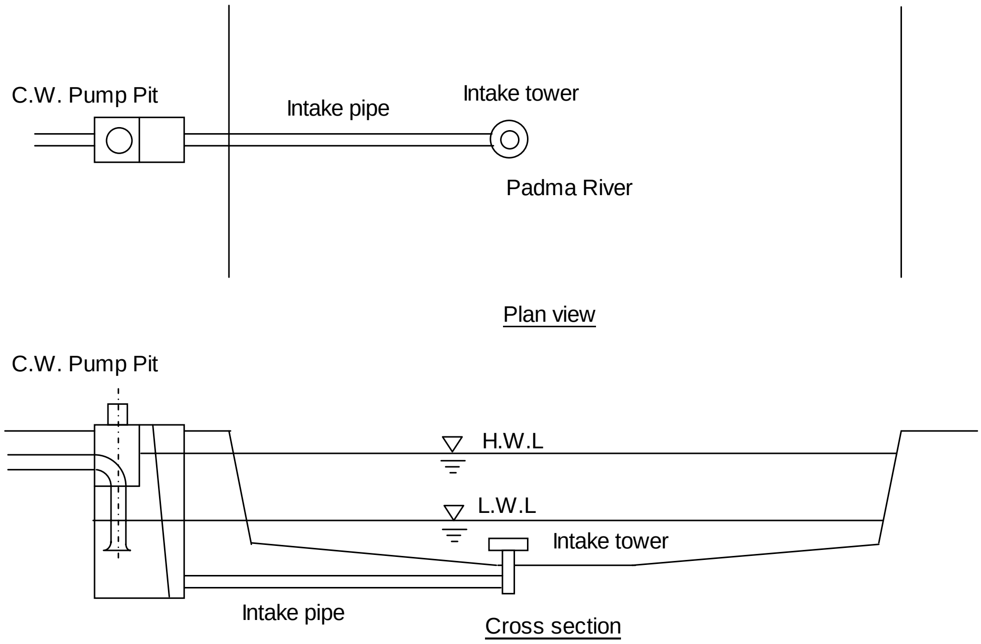


Figure I-4-7-6 Intake Tower

Based on the survey data as mentioned in Section 4.6.5 Water source (1) Hydrological and morphological data of Padma River, it is concluded that water intake by intake tower is impossible during dry (low-water) season due to the following reasons;

・cross section / level of the River bed is heavily fluctuated year by year
・for example, at 3,400m from the origin on left bank of the River (approximately 200m inside the River from the right bank), level of the River bed is fluctuated between EL +0.0m and EL+6.0m
・impossible to set the intake tower under the above conditions

2) Forced draft cooling tower system

Total makeup water of 1,300m^3/hr should be required. 1,200m^3/hr is for forced draft cooling tower system, approximately 50 m^3/hr is for HRSG and approximately 50 m^3/hr is for injection water to reduce NOx in case of oil firing.

According to the study of the above, it is impossible to take water directly from Padma River by both open cut and intake tower. Therefore, for taking relatively small amount of water, following two (2) types of water intake for makeup water of forced draft cooling tower system could be considered.

・Floating pump
・Deep well

a. Floating pump

Water intake directly from the surface of Padma River by floating pump

Conceptual drawing of floating pump is shown in the Figure I-4-7-7.

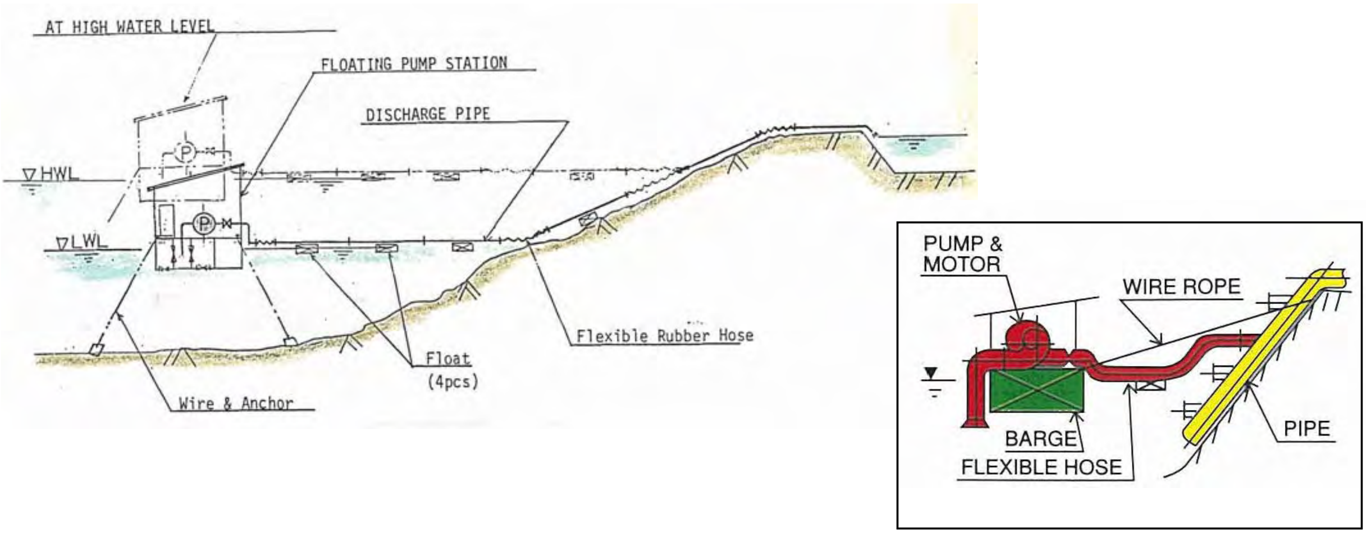


Figure I-4-7-7 Floating Pump

Based on the survey data as mentioned in Section 4.6.5 Water source (1) Hydrological and morphological data of Padma River, it is concluded that water intake by floating pump is not recommendable for permanent facility due to the following reasons;

- heavy anchoring facility to be required to prevent high velocity (approximately 3.5m/sec) during rainy season
- very long pipe inside the bank to be required to secure adequate draft of the barge during dry (low-water) season
- due to the high water level difference (H.W.L-L.W.L=approx. 9m), seasonal pipe level adjustment work to be required continuously

b. Deep well

Ground water intake through deep wells drilled beside the bank of Padma River
Conceptual drawing of deep well is shown in the Figure I-4-7-8.

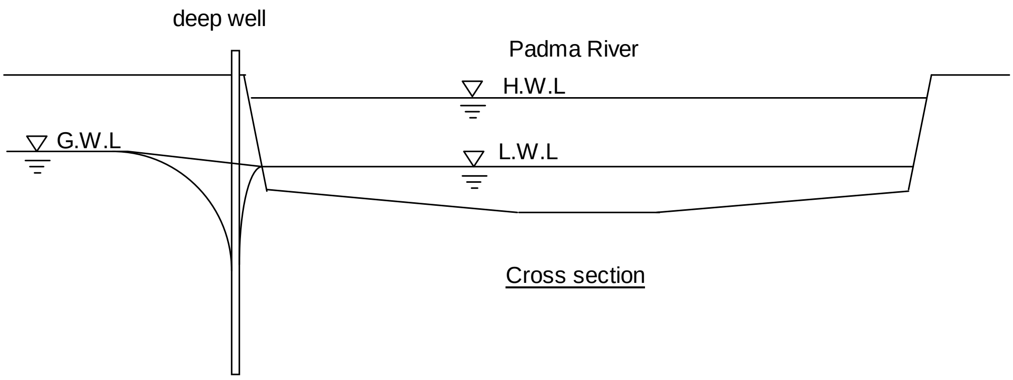


Figure I-4-7-8 Deep Well

Based on the groundwater investigation/study as mentioned in Section 4.6.5 (2) Groundwater investigation, it is concluded that natural aquifer condition of the site is suitable for supplying 31,200m^3/day (=1,300m^3/hr x 24hr/day) continuously without massive lowering of groundwater table. Therefore, Deep Well is adopted as water intake for forced draft cooling tower system.

Water wells sometimes do not work properly. Failure of the pump and the well screens are common problems. Therefore, extra wells might be needed to be kept ready for emergency requirements. Considering the above matters, well field with possible number of wells was designed as followings;

- capacity : 160m^3/hr/nos (160 x 12 = 1,920 m^3/hr = approx.1.5 x 1,300m^3/hr)
- quantity : 12nos
- distance : 140m

Figure I-4-7-9 shows well layout of the above.

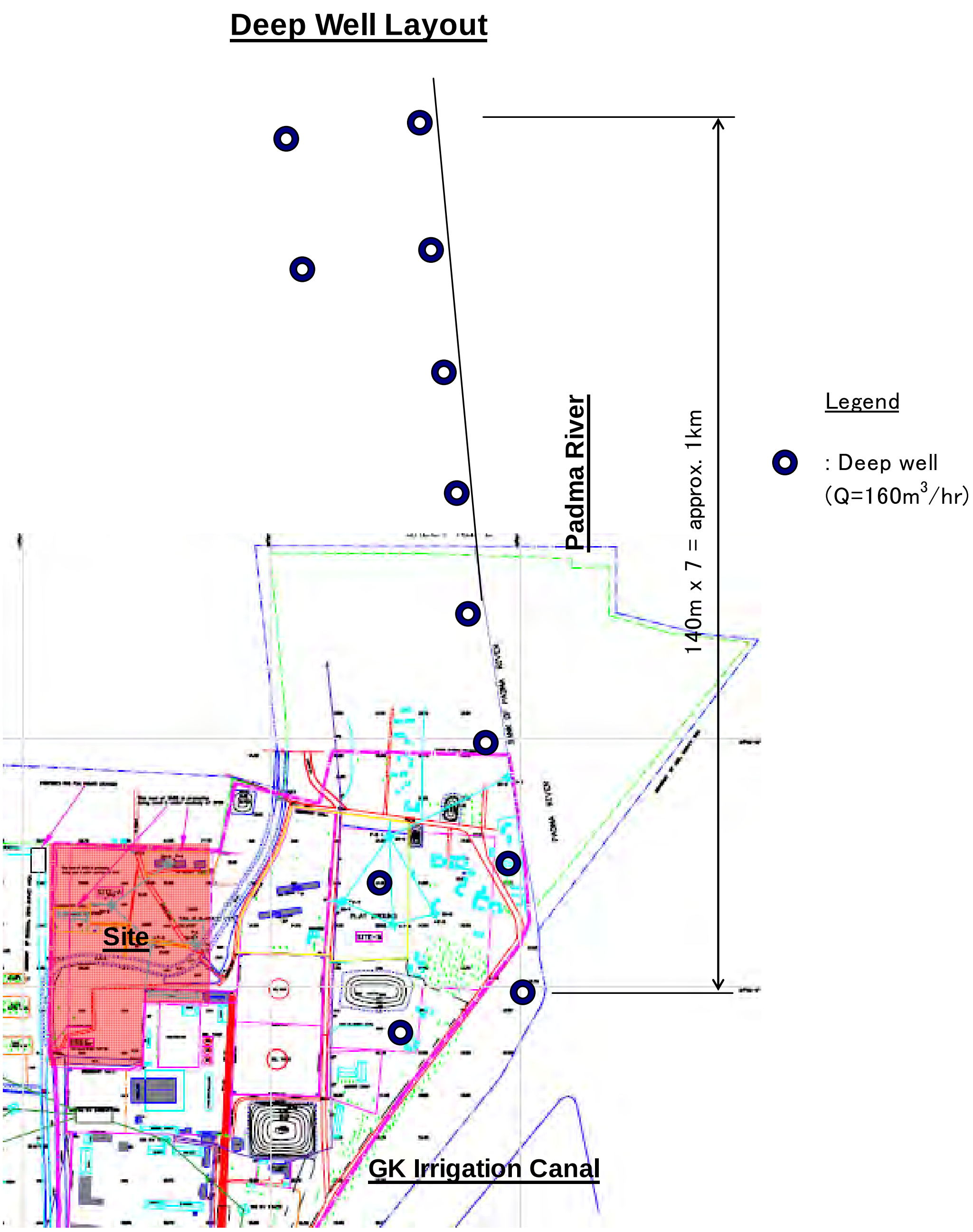


Figure I-4-7-9 Deep well layout

Groundwater table was simulated under the condition of continuous pumping of 31,200 m^3/day for 20years with the above well layout. Pump condition was set as following:

- -10 pumps are running (8pumps along the Padma River + 2pumps of upper and bottom end of inside line)
- -2pumps are reserve (2pumps of inside of inside line)

Simulation code

-MODFLOW: modular finite-difference flow model, which is a computer code that solve the 3-dimensional groundwater flow equation

-transient flow model simulation with a time step of one month

Model setting

Model boundary: distant boundary (BTM coordinate of 389318 to 412008 East and 653525 to 670026 North)

Aquiclude: GL-100m (Bottom of the aquifer has not been encountered in any bore hole. Bottom is deeper in actually.)

Model grid: 22.7km x 16.5km = 374km^2、100columns x 80rows = 8,000active cells （size: 227m x 206m）

Model grid is shown in the Figure I-4-7-10.

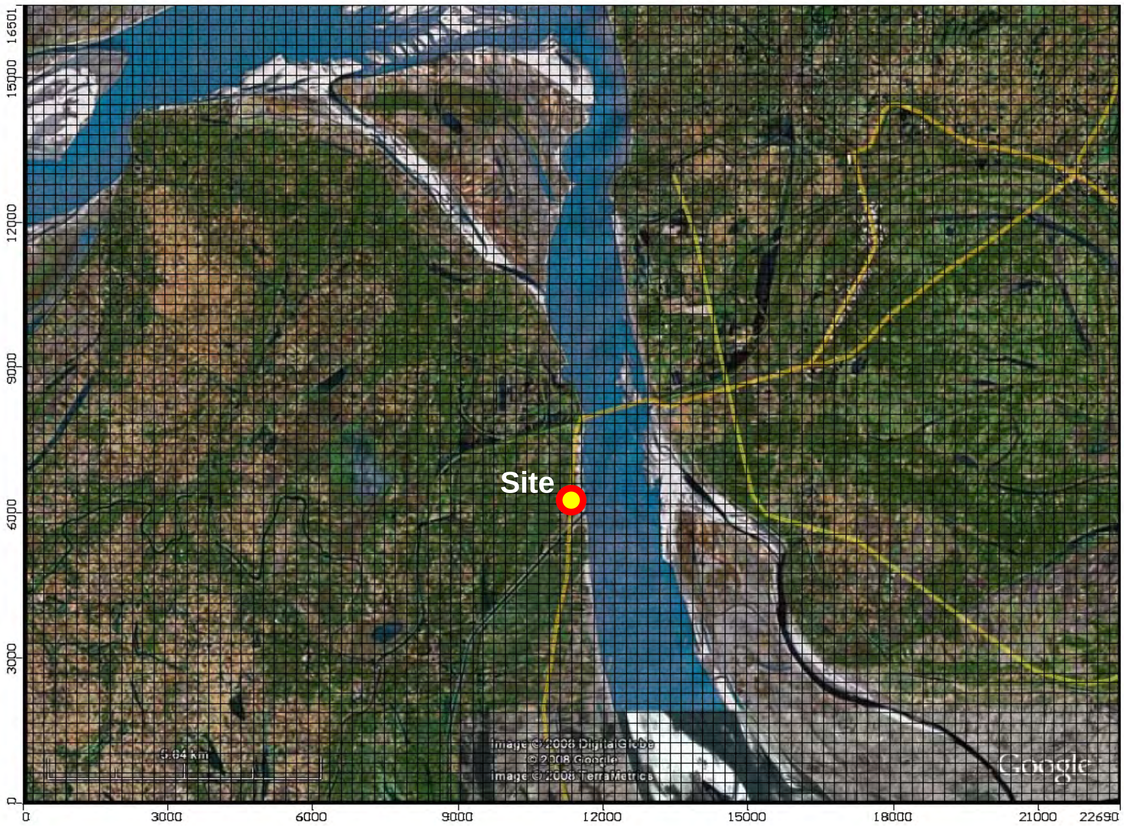


Figure I-4-7-10 Model grid

Hydrogeological parameter settings for the model are shown the Table I-4-7-24 and 3D view of the study area is shown in the Figure I-4-7-11.

Table I-4-7-24 Hydrogeological parameter settings for the model

Layer	Lithology	Thickness (m)	Kx m/d	Ky m/d	Kz m/d	Ss (1/m)	Sy (%)	Effective porosity (%)	Total porosity (%)
1	Clay and silt	0-36	1	1	0.1	0.0001	0.03	0.06	0.5
2	Very fine to fine sand	5-51	10	10	1	0.0001	0.18	0.18	0.2
3	Medium to coarse sand and gravel	75 +	45	45	4.5	0.007	0.25	0.27	0.3

Explanation: Kx = Hydraulic conductivity in the x direction, Ky = Hydraulic conductivity in the y direction, Kz = Hydraulic conductivity in the z direction, Sy = Specific yield, Ss = Specific storage.

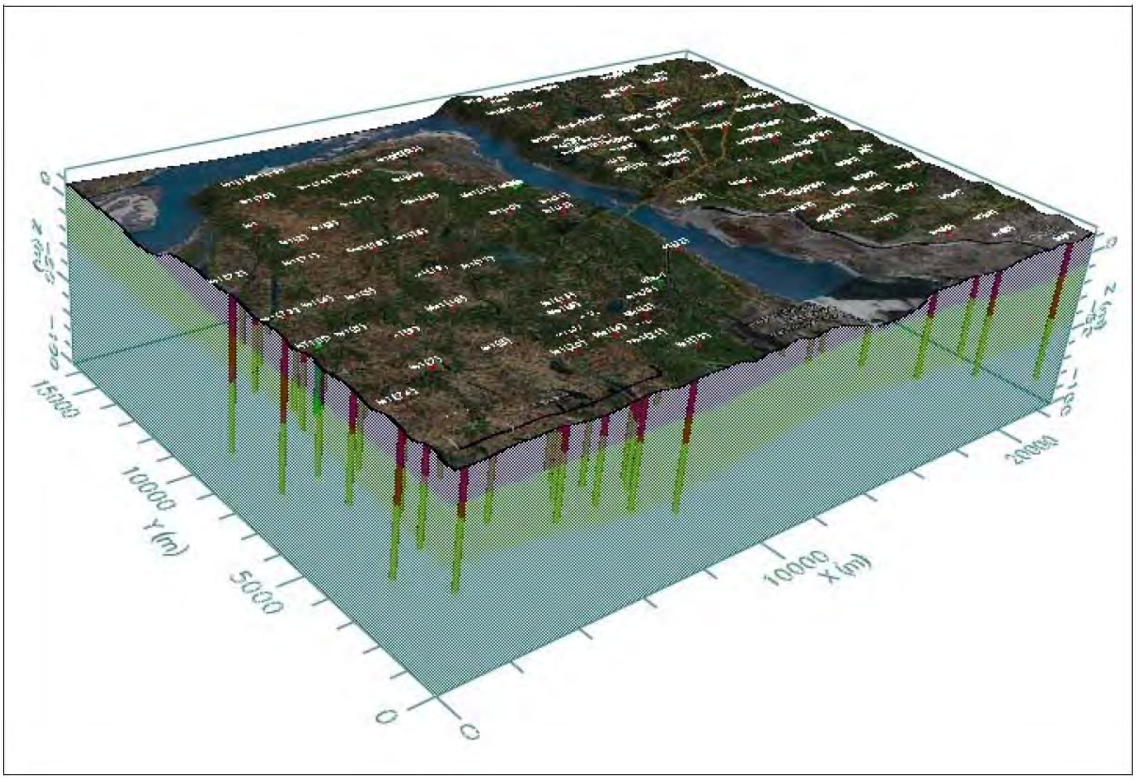


Figure I-4-7-11 3D view of the study area

<u>Input conditions</u>

-initial groundwater head potential distribution

-Padma river flow stage (water level)

-recharge estimates from the UNICEF (1993)

-evapotranspiration estimates made by Howard Humphre (1984)

-rate of abstraction from tubewells for urban and irrigation use (specified for individual modeled layers and grid cells)

Projected abstraction of groundwater for irrigation, domestic and municipal purposes is shown in the Table I-4-7-25.

Table I-4-7-25 Projected abstraction of groundwater for irrigation, domestic and municipal purposes

Year	Bheramara, Kushtia			Iswardi, Pabna		
	Groundwater Abstraction for irrigation (m^3/yr)	Groundwater Abstraction Domestic and Municipal Uses (m^3/yr)	Total Groundwater Abstraction (m^3/yr)	Groundwater Abstraction for irrigation (m^3/yr)	Groundwater Abstraction Domestic and Municipal Uses (m^3/yr)	Total Groundwater Abstraction (m^3/yr)
1st	61973100	2763272	64736372	45360000	4607702	49967702
2nd	63522428	2792839	66315266	46494000	4657005	51151005
3rd	65110488	2822722	67933210	47656350	4706835	52363185
4th	66738250	2852925	69591176	48847759	4757198	53604957
5th	68406707	2883452	71290158	50068953	4808100	54877053
6th	70116874	2914305	73031179	51320677	4859547	56180223
7th	71869796	2945488	74815284	52603693	4911544	57515237
8th	73666541	2977004	76643546	53918786	4964097	58882883
9th	75508205	3008858	78517063	55266755	5017213	60283969
10th	77395910	3041053	80436963	56648424	5070897	61719322
11th	79330807	3073592	82404400	58064635	5125156	63189791
12th	81314078	3106480	84420558	59516251	5179995	64696246
13th	83346930	3139719	86486649	61004157	5235421	66239578
14th	85430603	3173314	88603917	62529261	5291440	67820701
15th	87566368	3207269	90773637	64092493	5348058	69440551
16th	89755527	3241586	92997114	65694805	5405283	71100088
17th	91999415	3276271	95275687	67337175	5463119	72800294
18th	94299401	3311328	97610728	69020604	5521575	74542179
19th	96656886	3346759	100003644	70746119	5580655	76326775
20th	99073308	3382569	102455877	72514772	5640368	78155141

Calibration

In order to define the reproducibility of groundwater flow by the above mentioned model, process of calibration was undertaken. By cross matching the hydrographs of the observation wells, the model was calibrated to present the present groundwater conditions. Figure I-4-7-12 gives the matching of modeled water table with the observed water table in KTA-7. As shown in this figure, matching of the modeled water table with the observed water table was very well. Therefore, well reproducibility of the model was verified.

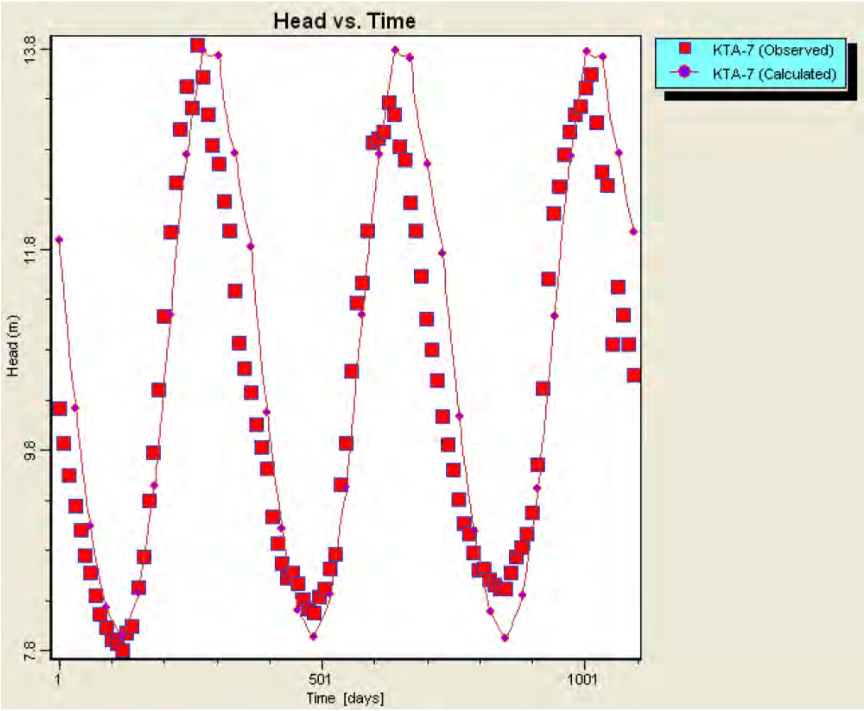


Figure I-4-7-12 Matching of observed and calculated hydrographs of KTA-7

<u>Simulation results</u>

Modeled dry season (May) water table contour map of the study area after 20 years of pumping is shown in the Figure I-4-7-13. Modeled wet season (September) water table contour map of the study area after 20 years of pumping is shown in the Figure I-4-7-14.

Contour of the Figure I-4-7-13 and I-4-7-14 shows groundwater level. In dry season (May), contour in a concentric fashion is going down to approximately EL+4.0m centering on the pumping point of the site. In wet season (September), contour in a concentric fashion is going down to approximately EL+11.0m centering on the pumping point of the site.

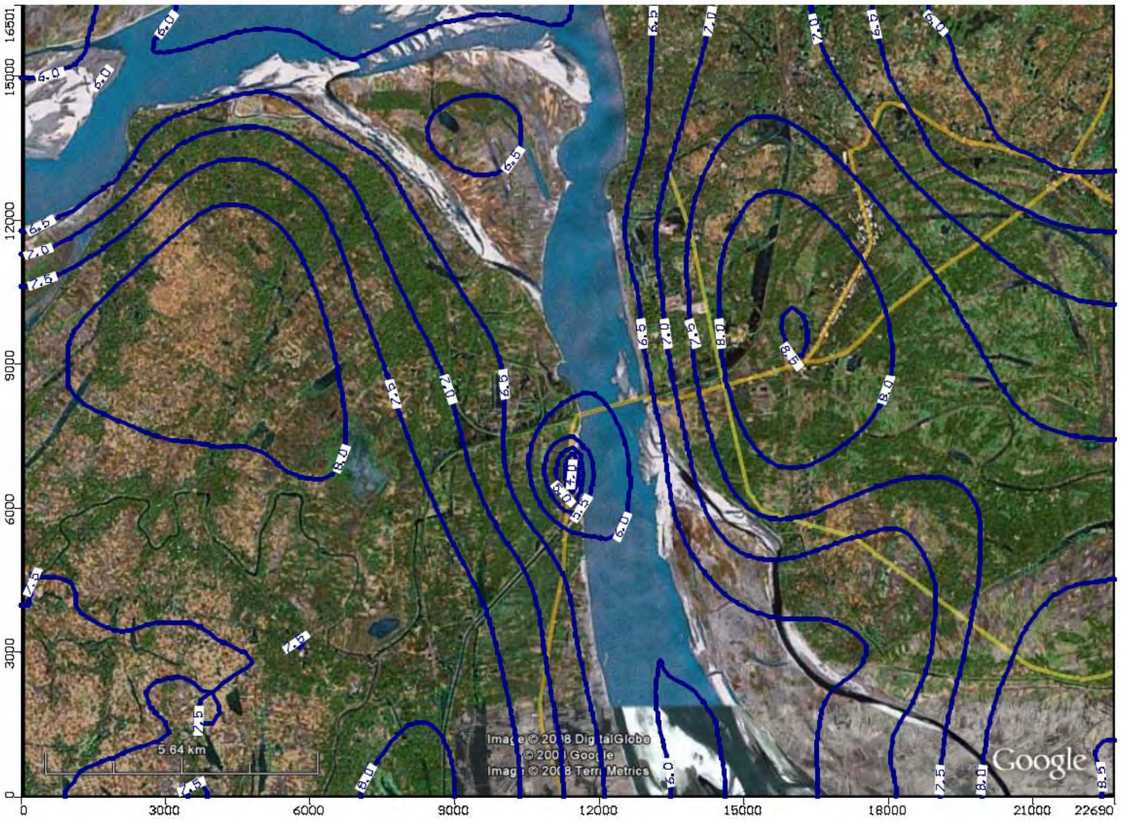


Figure I-4-7-13 Modeled dry season (May) water table contour map

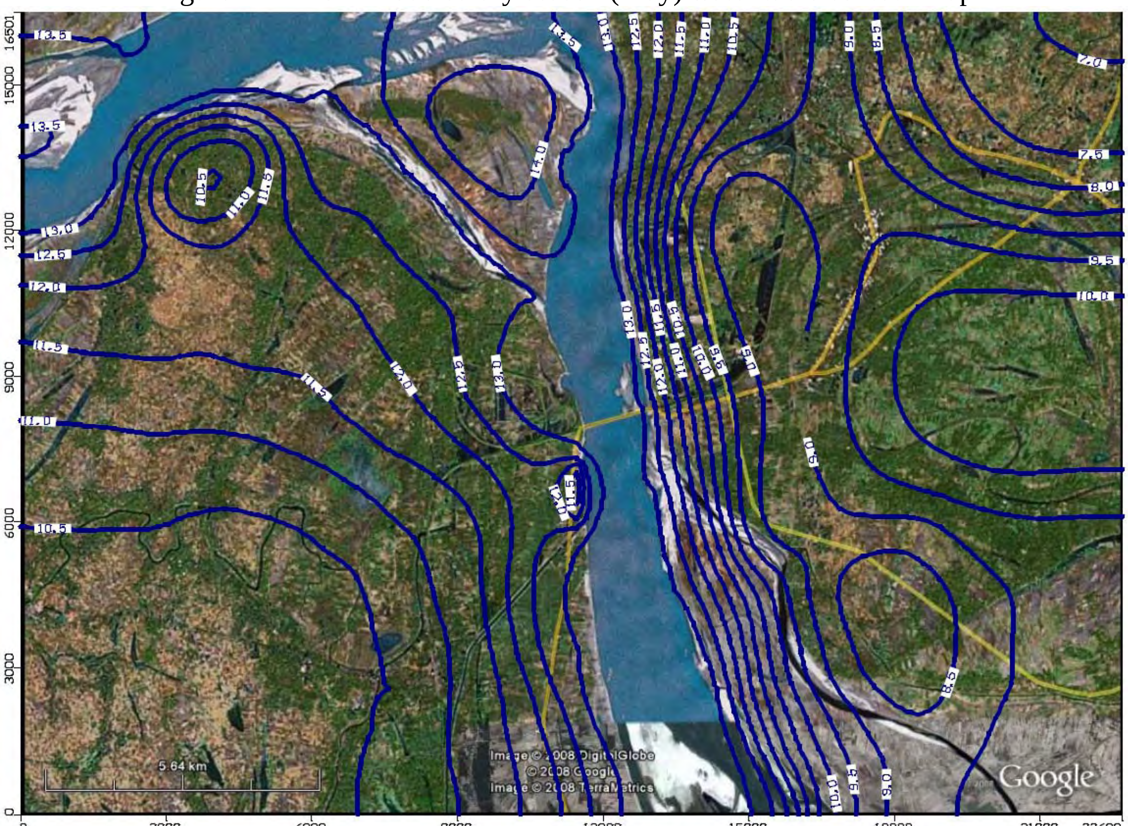


Figure I-4-7-14 Modeled wet season (September) water table contour map

Impact on existing tubewells

As shown in the Figure I-4-7-14, minimum groundwater level is approximately EL+11.0m, therefore, there is no impact on existing tubewells at all in wet season.

Zoomed modeled dry season (May) water table contour map of the study area after 20 years of pumping is shown in the Figure I-4-7-15.

Within the area of contour in a concentric fashion going down from approximately EL+6.0m to EL+4.0m centering on the pumping point of the site, groundwater table has been declined from the present condition approximately maximum 2m. Based on this result, Figure I-4-7-16 gives impacted area on existing tubewells.

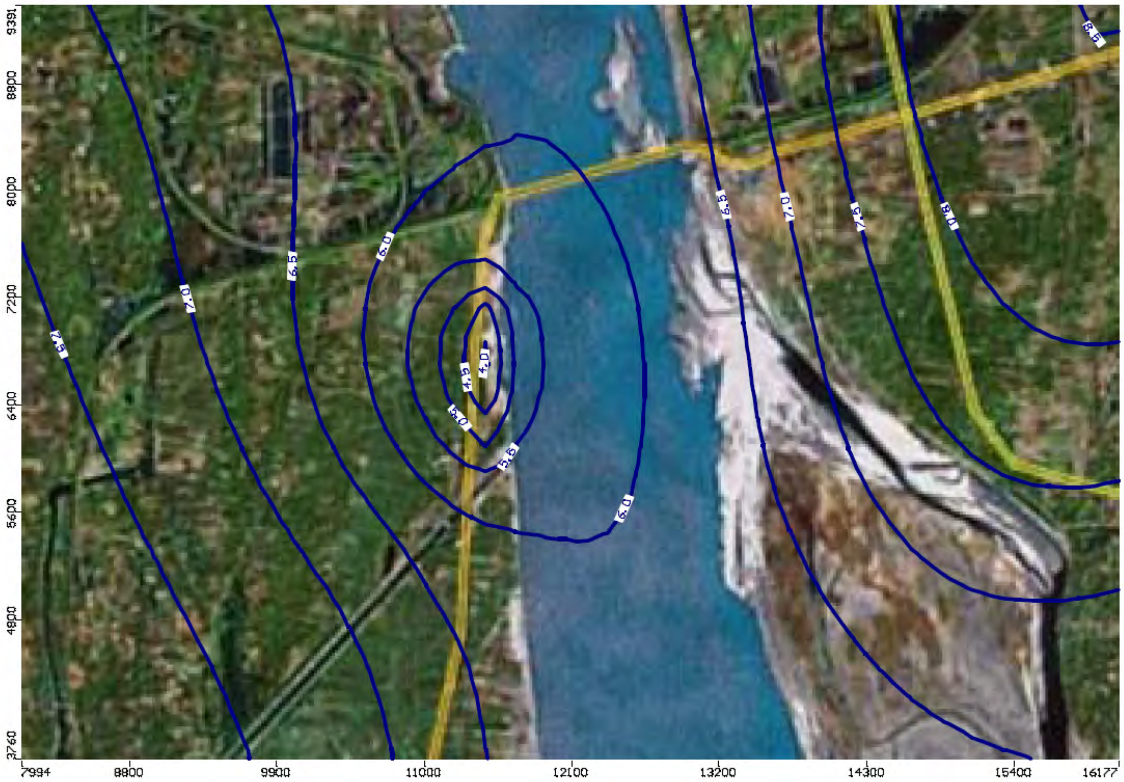


Figure I-4-7-15 Zoomed in modeled dry season (May) water table contour map

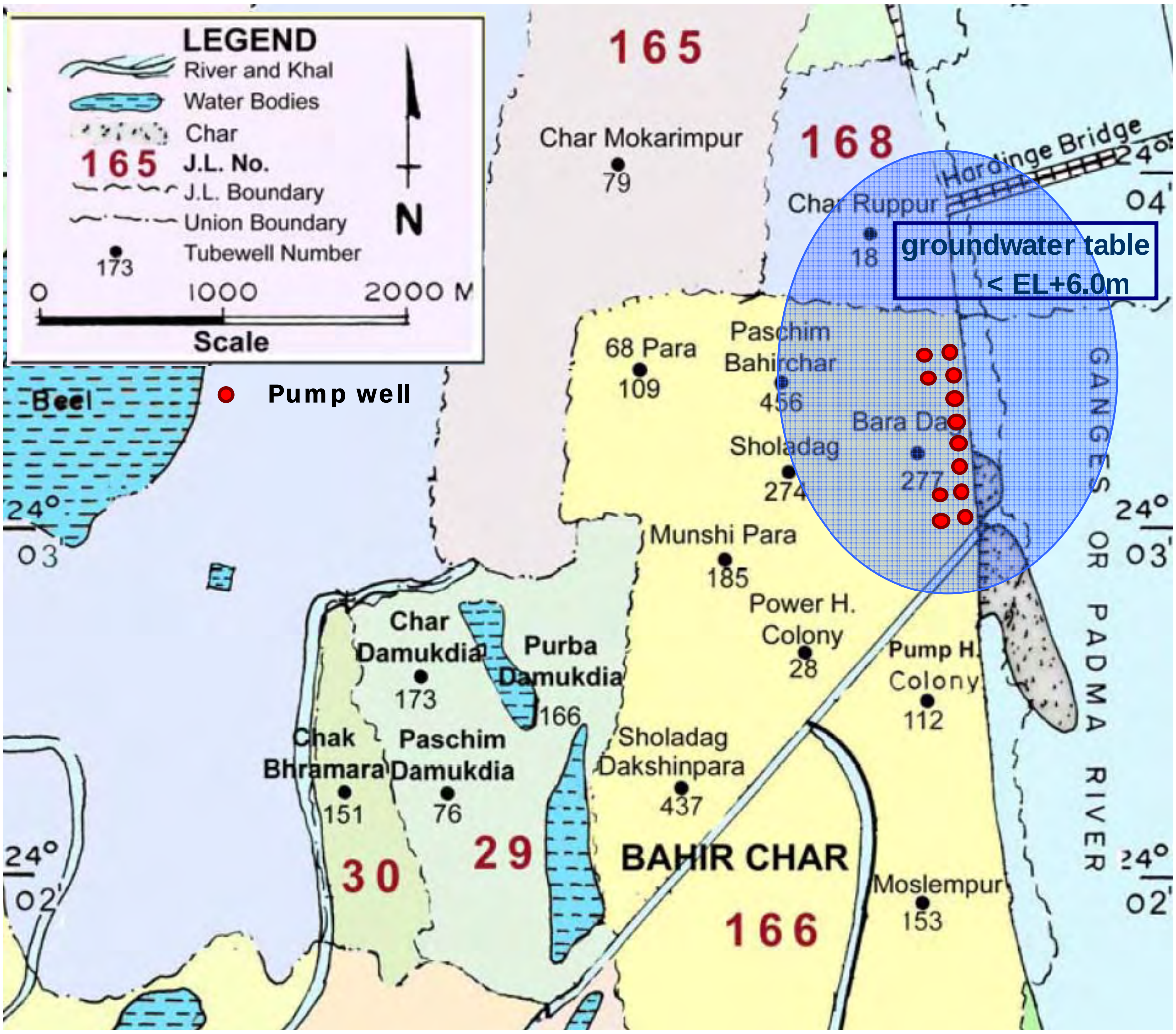


Figure I-4-7-16 Tubewells survey map with impacted area in dry season

As mentioned in Section 4.6.5 Water Source (2) Ground water Investigation, hand tubewell (HTWs) could operate only in suction limit of approximately 7.5m. Therefore, the above mentioned result of the study shows that HTWs in Char Ruppur Village, Bara Dag Village, Sholadag Village and Paschim Bahirchar Village might not suction groundwater in dry season.

On the other hand, shallow tubewells and deep tubewells have enough depth and would not be affected at all.

Table I-4-7-26 Impact on the existing tubewells

J.L. No.	Geo code	Locality	Area (km^2)	House Hold (nos)	Population (2001) (head)	HTWs (nos)	Water Bodies (nos)	Impact
30	**213**	**Chak Bheramara**	**0.81**	**196**	**929**	**151**	**11**	
165	**307**	**Char Mokarimpur**	**4.04**	**122**	**492**	**79**	**13**	
168	**331**	**Char Ruppur**	**1.28**	**28**	**346**	**18**	**17**	**Y***
29	**355**	**Damukdia**	**2.97**	**647**	**3,095**	**415**	**12**	
		Char Damukdia		181	936	173	4	
		Purba Damukdia		365	1,705	166	5	
		Paschim Damukdia		101	454	76	3	
166	**902**	**Pashchim Bahirchar**	**12.88**	**3,412**	**16,889**	**2,077**	**53**	
		Powerhouse Coloney		175	767	28	1	
		Bara Dag		279	1,420	277	4	**Y**
		68 Para		141	694	109	3	
		Moslempur		444	2,218	153	3	
		Munshi Para		241	1,174	185	4	
		Sholadag Dakshinpara		552	2,716	437	8	
		Sholadag		551	2,712	274	9	**Y**
		Paschim Bahirchar		856	4,334	456	13	**Y**
		Pumphouse Coloney		70	353	112	6	
		Bengal Para		103	501	46	2	

* : Y means "Yes, may be effected"

Based on the above result, HTWs in said four (4) villages especially Bara Dag Village besides the pumping points should be monitored carefully during plant operation period especially in dry season. In case HTWs which could not suction would be found, following countermeasure should be applied by NWPGCL.

Countermeasure

Deep set hand tubewell (DSHTWs) which could suction approximately 30-37m and is wildly used in Bangladesh (Tara pump) should be applied with enough depth covering groundwater table in dry season.

Detailed result of the groundwater investigation/study is shown in the Attachment 2 of Groundwater investigation report and Attachment 3 of Groundwater study report.

(3) Selection of Cooling System

1) Once-through cooling system

As mentioned above, in case adequate quality and quantity (approximately 30,000m^3/hr including cooling water for equipment) of water could be secured, this system is the best from both plant performance and economical (total of construction and additional cost) points of view.

Padma River near the candidate site was examined as the water source for cooling water. As mentioned in Section 4.7.4 (2) 1), however, it was confirmed that water intake was impossible during dry (low water level) season because of heavy sand sedimentation along the right bank of the River, very shallow water depth of the River, heavily fluctuated cross section/level of the River bed and others. Once-through cooling system could therefore not

be adopted.
Therefore, thermal effluent, which is one of the most serious environmental factors on Padma River, was eliminated.

2) Forced draft cooling tower system
This system is approximately 5,000kW less than Once-through cooling system in net power output, but almost same from economical point of view.
The required makeup water for this system is far smaller (1,300m^3/hr) than cooling water for Once-through cooling system (30,000m^3/hr), therefore, Floating pump as water intake directly from the surface of Padma River and Deep well as groundwater intake through deep wells drilled beside the bank of Padma River were studied.
As mentioned in Section 4.7.4 (2) 2), floating pump could not be recommendable as permanent facility. On the other hand, it was concluded that deep well could continuously pump up 1,300m^3/hr for a long time (plant running period) without massive lowering of groundwater table. Therefore, Deep well was adopted as water intake.
Consequently, environmental impact on Padma River was completely eliminated without any river water intake.

3) Forced draft air cooling system
This type of system has been used for the power generation plants which are built in areas where water sources are not available in the vicinity of plants as inland and desert areas, and is technically matured.
However, wider area should be required for setting this system, and as mentioned the above, this system is approximately 8,000kW less than Forced draft cooling tower system in net power output, and significantly less economical than another two candidate systems. Therefore, this system could only be applicable as the alternative measure in case another two systems could not technically be adopted.

4) Recommendation
As selection of cooling system for this project, three possible candidates of Once-through cooling system, Forced draft cooling tower system and Forced draft air cooling system were investigated/studied.
As the results of investigation/study, it was found that Once-through cooling system could not be adopted for cooling system of this project because of the difficulty to secure required amount of cooling water throughout a year. Forced draft air cooling system was also shelved because of its disadvantages in plant performance and economical viewpoint.
On the other hand, Forced draft cooling tower system is approximately 5,000kW less than Once-through cooling system in net power output, but almost same in economic efficiency. This system could continuously be secured enough amount of water by pumping groundwater through Deep well for makeup water without massive lowering of groundwater table. It is therefore, concluded that Forced draft cooling tower system could be recommendable for the cooling system of this project. In this regard, however, some existing shallow wells around the site would possibly be disturbed; therefore, such existing wells should be carefully monitored during the site operation especially in dry season and be taken appropriate measures as deep set hand tubewell (DSHTWs) with enough depth to secure constant supply of adequate amount of groundwater if it is required by NWPGCL.

4.8 Equipment and materials transportation

Power generation plants including steam cycle are normally constructed at seacoast or rivercoast can easily supply the cooling water and directly transport heavy weight or large volume cargoes

to site by ships.
The Bheramara site is located in the vicinity of the upstream of the Padma River. The water level of the Padma River in the vicinity of the Bheramara site is changing throughout the year and the water level change is maximum 10m. Accordingly, when the heavy weight equipment and materials (herein after heavy weight cargoes) required for the construction of the Bheramara site are to be brought into the Bheramara site from overseas countries, the EPC contractor may not be able to transport the heavy cargoes into the Bheramara site as planned. To solve this problem, we conducted the transportation survey and study including overland transportation for heavy weight cargoes in this survey.

4.8.1 Procurement of equipments and materials

Total transportation weight including heavy weight cargoes is approximately 30 thousand ton. The 10 thousand ton is equipment such as gas turbine, HRSG, steam turbine etc. and the 20 thousand ton is materials such as cement, aggregate, sand, rebar etc.
Equipment required for the construction of the Bheramara site are almost imported from overseas countries. Materials such as cement, aggregate, sand, rebar etc. can be procured in Bangladesh. Government of Bangladesh does not permit import of these materials can be procured within Bangladesh.

4.8.2 Heavy weight equipment transportation

Survey and study of heavy weight equipment transportation is required in the equipment and materials transportation. The heavy weight equipment required for the construction of the Bheramara site include a gas turbine as the main engine, steam turbine, HRSG, generator and transformer.
The typical packing lists used in this survey and study are shown in Table I-4-8-1 to Table I-4-8-4.

Table I-4-8-1 Packing list (gas turbine)

DESCRIPTION	Q' ty	PER ONE PACKAGE				
		WEIGHT (Ton)		MEASUREMENT(m)		
		Net	Gross	L	W	H
Gas Turbine						
Rotor-Comp. & Turbine						
Gas Turbine Lower Cylinder						
Inlet Casing-Comb. Cylinder Upper	1	351	367	14	6	6
Turbine Cylinder Upper						
Exhaust Cylinder Upper						
Lube Oil Tank	1	44	44	7	4	4
Turbine Cooling Air Cooler	1	70	73	9	5	4

Table I-4-8-2 Packing list (steam turbine)

DESCRIPTION	Q' ty	PER ONE PACKAGE					
		WEIGHT (Ton)		MEASUREMENT (m)			CUBIC
Steam Turbine		Net	Gross	L	W	H	(m^3)
HIP Turbine Assembly	1	110	118	8.20	3.50	3.80	109.06
Rotor Assembly	2	61	83	10.03	4.25	4.10	174.77
Outer Casing (Lowerr)	2	44.0	48.6	7.50	7.30	3.20	175.20
Condenser shell with Tubes & Hotwell	2	98.50	101.10	11.60	6.10	4.10	290.12

Table I-4-8-3 Packing list (HRSG)

Equipment	Qty/ HRSG	Width/ each (m)	Height/ each (m)	Length/ each (m)	Volume (m^3) HRSG	Weight/ each (ton)	Weight/ HRSG (ton)
RHTR3 & HPSHTR2 COILS	3	4.03	2.74	23.32	257.93	59.15	177.46
RHTR1 & HPSHTR1 COILS	3	4.03	2.54	23.16	236.81	72.85	218.56
HPEVAP COIL	3	4.00	2.74	23.27	255.42	128.18	384.55
HPECON2F, IPSHTR, IPEVAP & LP. SH2 COILS	3	3.98	3.73	23.27	345.80	160.12	480.35
HPECON 1/ I, LP.SH 1 & LPEVAP.COILS	3	3.97	2.84	23.27	262.76	153.45	460.36
PREHTR 2 COIL	3	3.68	2.33	22.55	193.23	97.75	293.25
PREHTR 1 COIL	3	3.95	2.72	22.55	242.43	97.48	292.45
HP. Drum	1	2.55	16.14	16.14	665.81	84.53	84.53

Table I-4-8-4 Packing list (generator)

DESCRIPTION	QTY	PER ONE PACKAGE					
		WEIGHT (TON)		MEASUREMENT (m)			CUBIC
		NET	GROSS	L	W	H	(m^3)
GTG Stator with Gas Cooler and Rotor	1	286.4	294.0	14.1	4.6	5.1	330.8
GT Transformer	1		155.0	7.7	3.0	5.7	131.7
ST Transformer	1		120.0	5.7	2.5	4.8	68.4
Start up Transformer	1		89.0	4.0	2.1	4.0	33.6
Unit Transformer	1		89.0	4.0	2.1	4.0	33.6
230/132k V Bus-tie Transformer	2		113.0	5.3	2.4	4.6	58.5

4.8.3 Transportation limit

Transportation limit in overland transportation is as indicated below.

(1) Transportation limit

Highways in Bangladesh are designed with 10 ton based on the axitial load of truck and trailer and bridges and culverts are designed with 35 ton per pier span or lane.

The axitial load less than 10 ton in overland transportation is required.

Overland transportation weight limit is restricted below 40 ton according to regulation of “Gazette Notification of Government Regulation regarding Carrying Capacity of Road” and road administrator opinion of “Letter of Superintending Engineer, Roads & Highway Department (RHD) on Carrying Capacity of Road”. Therefore Heavy weight cargoes over 40 ton are necessary to consider channel transportation.

If cargo weight is below 40 ton and cargo size is below width 2.5m x height 2.5m x length 6m or width 2.5m x height 2.5m x length 12m and transported with precaution then there is no necessaity of obtaining permission from the road administrator.

In case of existing Mymenshingh CCPP (Output 2 units x 70MW, 2 units x 35MW) heavy weight cargoes over 100 ton with permission of road administrator were transported from Kanchpur to Mymensingh by trailers. Mymensingh case means if the permission of road administrator is obtained heavy weight cargoes over 40 ton can be transported by trucks or trailers in this project.

(2) Overland transportation of heavy weight cargoes in existing Mymenshingh CCPP

Heavy weight cargoes over 100 ton have been transported by trailers with permission of road administrator in existing Mymenshingh CCPP (output 2units x 70MW, 2 units x 35MW). Cargoes transported by overland transportation are two gas turbines and two generators.

The information regarding overland transportation of heavy weight cargoes in existing Mymenshingh CCPP is as indicated below.

Item	Content
Heavy weight name	GT x 2 units, 100 ton/unit GT generator x 2 units, 110 ton/unit
Trailer	12 shafts, 96 wheels Imported from Netherlands
Transportation route, distance, period and time zone	Transportaion route: Mongla port～Kanchpur (Channel) Kanchpur～Mymensingh (overland) Transportation distance: 145 km Transportation period: 10 days/cargo Time zone: midnight
Repair and renovation of roads, bridges, culverts etc.	Roads & Highways Department (RHD) did not allow the loaded trailer to passing over any bridge or culvert on the entire highway. Following arrangements were involved: ・ Fabrication of two sets of 5.0m, two sets of 10.0m and one set of 18.0m long deck-girder type portable steel bridges for over-passing small bridges, culverts of 3.0m, 8.0m and 15.0m length. The temporary girder type portable bridges were also transported along with the consignment for use-as-required basis. ・ Construction of bridge by-passes (detour) at 8 places to avoid existing small bridges of more than 15.0m long. ・ Construction of temporary earthen cross-dams at two places for river crossings. Largest cross-dam was about 800.0m long at Mymensingh for crossing the river Brahmaputra. ・ An improvised ferry-barge was used to cross the river Turag between Uttara-Tongi.
Construction of bypass roads, bridges and application procedure to road administrator:	Special permits were obtained from the following agencies for the transportation job; ・ Roads & Highways Department: For passing over the national highway. ・ Dhaka City Corporation: For passing over the city roads under Dhaka Municipal Corporation. ・ Bangladesh Inland Water Transport Authority (BIWTA): For construction of ramps in connection with crossing of the river Turag at Uttara-Tongi. ・ Bangladesh Water Development Board (BWDB): For construction of by-pass embankments/ cross-dams at various places for river-crossing. ・ Local electricity distribution companies for temporary relocation of overhead electricity lines where came in way (obstruction) of the consignments.

Item	Content
	These agencies were, PDB, DESA and REB.
Required application time	Minimum three (3) months application time may be considered.
Government name for application of heavy and large cargoes over regulation and Regulation for Heavy and Large Cargoes:	Roads and Highways Deptt.(RHD) and Bangladesh Railway (BR) have their own regulations for heavy and over-sized cargoes. RHD regulations depend on the type of pavement, bridges. They also have their own allowable maximum moving dimension lists for different routes.
Transportation cost	GT (100 ton weight) transportation cost is approximately 1 million USD. Transportation unit cost per ton weight is ten thousand USD.

4.8.4 Survey and study policy

In this project equipment below 40 ton are approximately 5.5 thousand ton and over 40 ton are 4.5 thousand ton. Approximately equipment of 4.5 thousand ton will be transported by channel transportation.
In this study heavy weight cargoes over 40 ton of overland transportation weight limit were studied by channel transportation according to the regulation and road administrator opinion in section 4.8.3. Cargoes below 40 ton were studied by overland transportation from Mongla port to Bheramara site.

4.8.5 Selection of candidate transportation routes

Candidate transportation routes for cargoes transportation from overseas to Bheramara site shown in section 4.8.2 are as indicated below.

(1) First unloading port in Bangladesh

As first unloading port in Bangladesh representative Mongla port and Chittagong port were selected and the qualification was surveyed and studied.

1) Mongla port

The port facilities are sufficient to handle any cargo dispatched by ocean going vessels in all seasons but heavy weight cargoes over 100 ton shall be unloaded by cranes from ship to the barges in the outer anchorage.
Port facilities in Mongla port are shown in Table I-4-8-5.

Table I-4-8-5 Port facilities in Mongla port

Facility name	specification
Jetty length	600m
Jetty draft	6～7m（usual dredging）
Number of jetty	Existing 5 jetties, future 2 jetties
Crane	5ton x 4 units
Transit shed	19,628m2 x 4
Ware house	19,630m2 x 2
Open dump	3,000,000m2
Container storage space	Container yard 35,754m2 x 3、2,180Teus

2) Chittagong port

The heavy weight cargoes should be unloaded from ship on to the barges by cranes in the outer anchorage area considering the draft of large cargo ship. But in monsoon season, sea remains very rough condition and unloading from ship to barges is less possibility by rolling and pitching.
No equipment can be unloaded in the Chittagong port during monsoon season which rivers are very good for navigation.
Though the coast line near Chittagong port is safe for navigation in dry season, Padma river becomes dry and no heavy equipment can be transported by barge through Padma river.
Chittagong port is greatly crowded with ships except for January and February

3) Selection result for first unloading port in Bangladesh
Mongla port was selected as first unloading port in Bangladesh which heavy weight cargoes can unload in all season and agreed by BPDB.

(2) Candidate transportation routes
3 candidate transportation routes from Mongla port as indicated below were selected and agreed by BPDB.

Route 1 : Channel transportaion :
Mongla port – River Ganges – River Padma – Bheramara site
Route 2 : Channel transportation and overland transportation
Mongla port – River Ganges – River Jamuna – Sirajganj site (channel)
Sirajganj site – Bheramara site (overland transportation)
Route 3 : Overland transportation
Mongla port – Bheramara site

Candidate transportation routes for heavy weight cargoes is shown in Figure I-4-8-1.

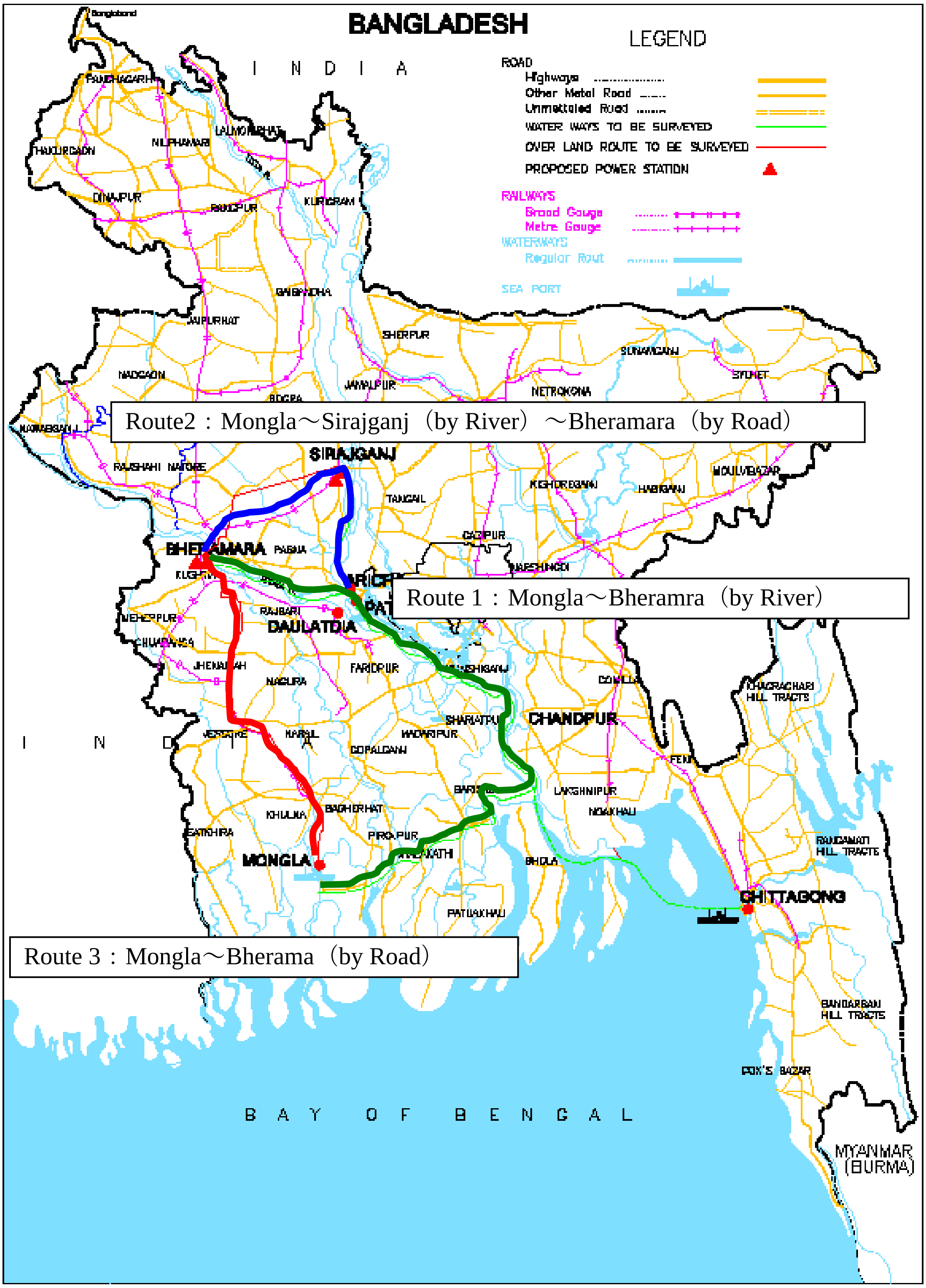


Figure I-4-8-1 Candidate transportation routes

4.8.6 Survey of candidate transportation routes

(1) Mongla port to Bheramara site (channel transportation)

This route goes upstream on Ganges river and Padma river from Mongla port to Bheramara site. These river have several km width and considerable degree of water quantity and high water level in monsoon season. On the other hand, these river water level comes down in dry season as holms comes from river. Especially water depth of Padma river is shallow and can not navigate through the year. Therefore channel transportation period can keep the applied barges draft in heavy weight equipments transportation shall be studied.

1) Channel survey results

Survey was conducted for channel depth, width and the condition from Mongla port to Bheramara site.

Total distance of this transportation route is approximately 377 km.

Summary of channel width and depth from Mongla to Bheramara is shown in Table I-4-8-6.

The depth is over 4.5m at center of the river and it is enough depth for navigating barges with maximum capacity 600 ton and tag boats with draft 1.22 to 2m.

Though Gabkhan bridge as obstruction for navigation is at 89 km apart from Mongla port, there is no problem for channel transportation of heavy weight cargoes in this project because distance between Bridge bottom and barge deck is 8 m.

Table I-4-8-6 Summary of channel width and depth from Mongla to Bheramara

Mongla-Hizla-Daulatdia-Bheramara (Survey from 14.07.2008 to 27.07.2008)					
Section	Distance (km)	Width (m)	Depth (m)		
			0.25W	Mid Point	0.75W
Mongla to Morelganj	38	200-1000	4.4-10.4	4.6-10.2	3.0-10.4
Morelganj to Kawkhali Ferighat	38-77	700-2500	7.5-15.9	9.5-22.1	8.5-16.1
Kawkhali to Barisal CSD Ghat	77-114	120-800	5.0-23.9	6.2-24.4	4.4-24.1
Barisal to Hizla	114-142	300-1700	4.3-19.3	5.3-25.0	4.3-23.0
Hizla to Chandpur	142-193	600-10000		4.8-40.5	
Chandpur to Mawa	193-241	300-3900		4.8-27.1	
Mawa to Daulatdia	241-295	900-5300		11.5-53.9	
Daulatdia to Nazirganj	295-321	3000-6000	4.1-18.6	4.5-27.5	4.2-20.1
Najirganj to Shilaidaha	321-353	2000-4000	3.7-19.1	4.5-30.0	4.4-28.1
Shilaidaha to Talbaria	353-365	2500-3500	6.5-19.6	9.6-26.3	9.2-25.1
Talbaria to Bheramara	365-377	2000-4000	5.6-15.2	7.5-18.2	5.3-15.8

Photographs of channel transportation route from Mongla port to Bheramara site is shown in Photograph I-4-8-1 and Photograph I-4-8-2.

Photograph I-4-8-1 The Ganges river at Dauladia

Photograph I-4-8-2 Ganges near Hardinge Bridge

2) Available period for channel transportation

The Ganges river from Mongla port to Daulatdia can be used throughout the year as informed by Banglaesh Inland Water Transport Authority (BIWTA). Barges and tugboats with draft 1.5m – 2m can navigate through the year. Applied biggest 600 ton barge's draft is 1.22m and tugboat's draft is 2m. Therefore channel transportation from Mongla port to Daulatdia was possible from July to September was clarified.

Water level falls too much in the dry period from termination of monsoon. Rivers particularly Padma river from Daultatdiaghat to Bheramara is shallow. Deep channels are narrow and non continuous. Suitable time is during wet monsoon from July to September. This appears to be most suitable route.

The River water level data for past 30 years (see Figure I-4-8-2) at 1 km down river of Hardinge bridge near Bheramara site received from BPDB shows river water level data from July to September is approximately same. Channel water depth from August to September is enough for barge transportation was clarified by comparison of these water level data and channel water depth data shown in Table I-4-8-6.

River bed is unpredictable on account of rapid siltation on slight change in river flow. A dredger of adequate size and pilot service from IWTA will have to be arranged along the Ganges river route from Daultatdiaghat to Bheramara.

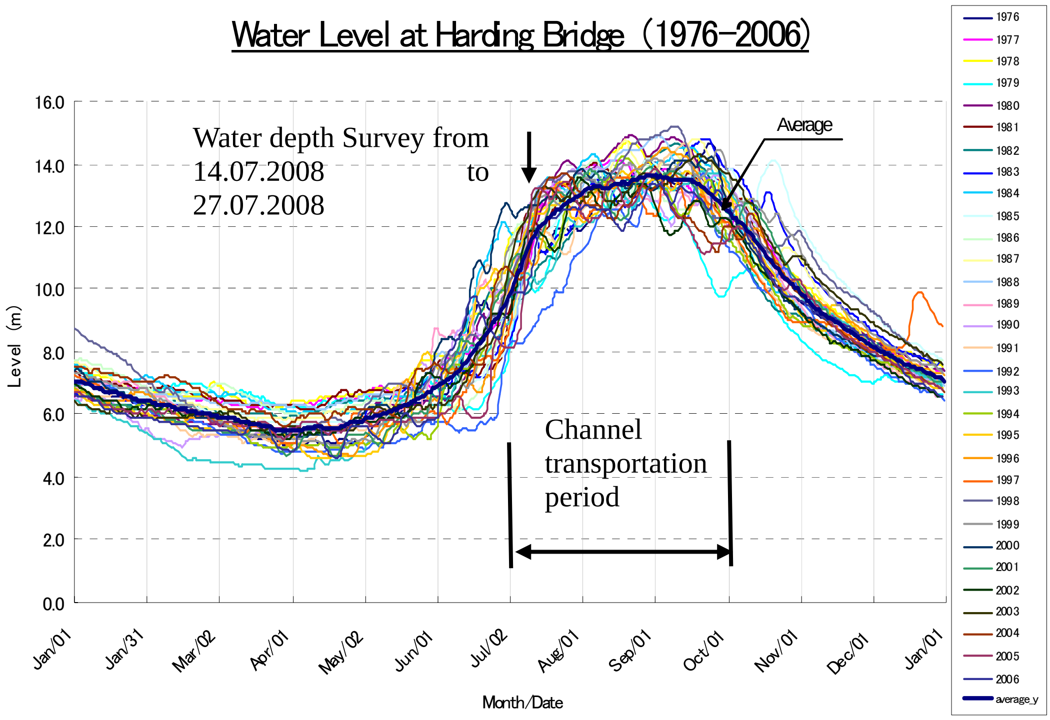


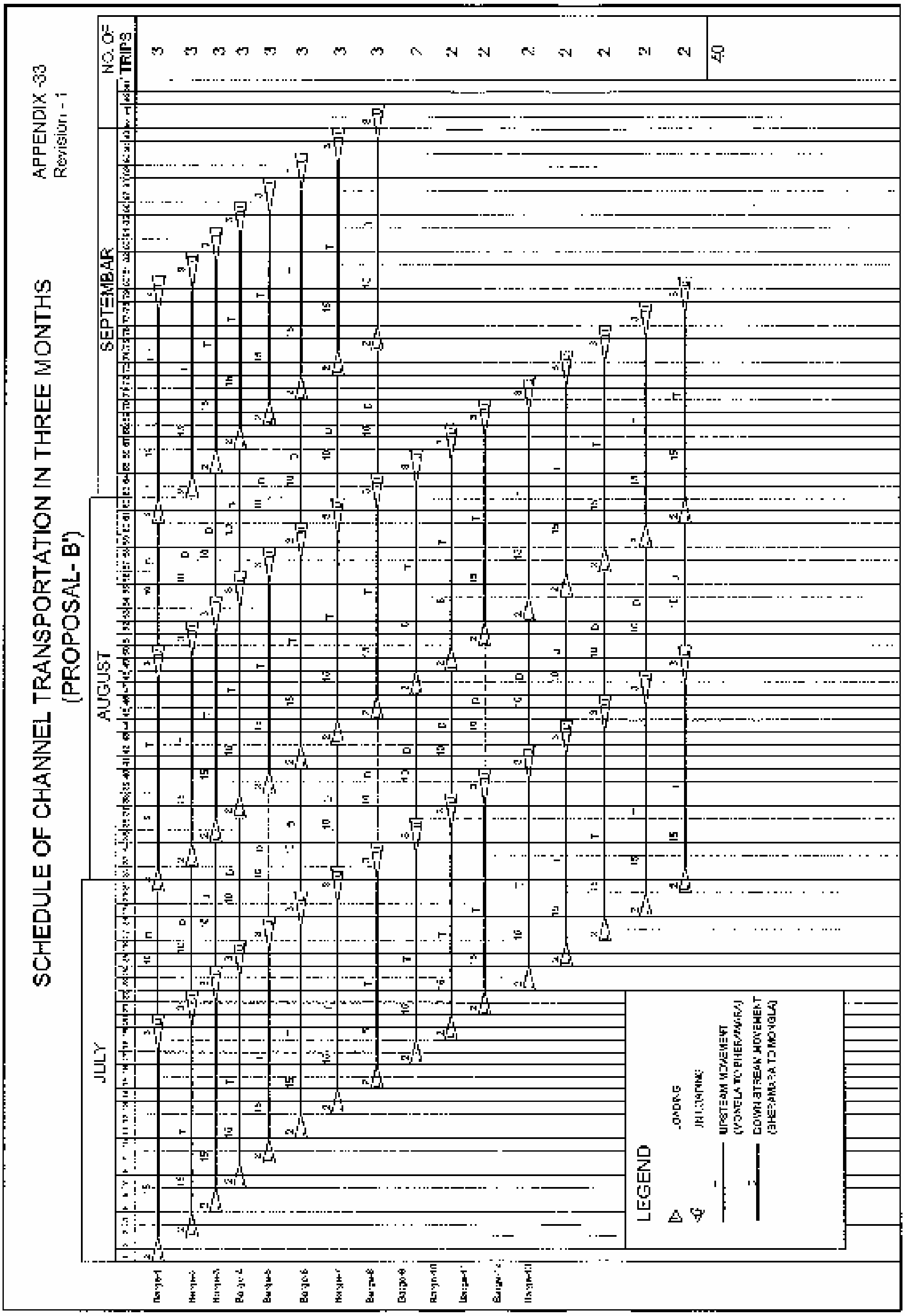
Figure I-4-8-2 The River water level data for past 30 years at 1 km down river of Harding bridge

3) Channel transportation schedule

Examination case of channel transportation by barges and tugboats from Mongla port to Bheramara site is shown in Table I-4-8-7.

Table I-4-8-7 Channel transportation by barges and tugboats from Mongla port to Bheramara site

Total round trips	40 from Mongla port to Bheramara site
Travel time per round trip	30 days (15 days up stream & 10 days down stream, 5 days for loading and unloading)
One round barge trip	1 barge and 2 tugboats : 2 tugboats tows loaded barge up stream from Mongla to Bheramara, 1 tugboat tows empty barge down stream from Bheramara to Mongla and other is idle.
Transportation period	About 3 months
Running time of barge	10 hours per day up stream speed of barge : 2.5 km/h, down stream speed of barge : 3.8 km/h)
Note	1 barge and 2 tugboats will be adopted for 2 or 3 round trips, total 16 barges and 32 tugboats for 40 round trips have to be adopted to complete the transportation within about 3 months. Heavy weight cargoes of about 4,500 tons will be transported from Mongla Port to Bheramara by channel transportation within about 3 months.



(2) Mongla port to Sirajganj site (channel transportation) ～Bheramara site (overland transportation)

1) Mongla port to Sirajganj site (channel transportation)

Route survey from Daulatdia to Sirajganj was conducted for channel depth, width and the condition.

The river route from Mongla port up to Sirajganj is about 365 km long.

Route survey results from Mongla port to Daulatdia already has been mentioned in section 4.8.6 (1).

Jamuna river from Daulatdiaghat to Sirajganj can navigate from July to September.

River bed is unpredictable on account of rapid siltation on slight change in river flow. A dredger of adequate size and pilot service from IWTA will have to be arranged along the Jamuna river route from Daultatdia to Sirajganj.

Summary of channel width, depth and the condition from Daulatdia to Sirajganj is shown in Table I-4-8-8.

The depth is over 4.8m at center of the river and it is enough depth for navigating applied biggest 600 ton barges with draft 1.22 to 2m.

Table I-4-8-8 Data of channel width and depth from Daulatdia to Sirajganj

Daulatdia-Sirajganj (Survey from 14.07.2008 to 22.07.2008)					
Section	Distance (km)	Width (m)	Depth (m)		
			0.25W	Mid Point	0.75W
Daulatdia to Chowhali	295-332	2000-7000	6.0-37.1	6.2-39.3	4.9-29.9
Chowhali to Sirajganj	332-365	500-6000	5.6-30.6	4.8-32.2	4.8-31.9

The channel condition from Daulatdia to Sirajganj is same condition from Daulatdia to Bheramara site on available period for channel transportation and can not navigate through the year, therefore this channel route from Daulatdia to Sirajganj has no merit was clarified.

Candidate jetty positions at Sirajganj site are shown in Figure I-4-8-3.

At present there is neither any jetty on the riverbank nor any unloading equipment at Sirajganj site.

The river Jamuna is at 1 km east of the Sirajganj site.

No construction works of Sirajganj site has started and no jetty point has been selected.

One is a jetty point on the down stream of river training guide bund of the right bank of the river Jamuna. But the Jamuna Multipurpose Bridge Authority (JMBA) would not permit any body to interfere on the river training guide bund. Therefore this jetty point is not suitable.

Another one is a jetty point within the property of Sirajganj site. A 500 m wide and 3.05m deep stream is flowing about 500 m away from the riverbank. Transportation of any cargo to the project site is not possible during dry season through this channel. This jetty should be constructed by the IPP until the time cargoes transportation in Bheramara site would start. But during construction period of Sirajganj site, unloading activities of heavy weight equipment for Bheramara site will hamper progress of Sirajganj site and IPP authority will not allow unloading equipment of other agencies in the same compound using their facilities. The approach road is not designed for heavy weight cargoes. More over there are two 90 deg bends in the approach road. Temporary road will require to be constructed. So this route is also not suitable for unloading of heavy weight cargoes in the Bheramara site.

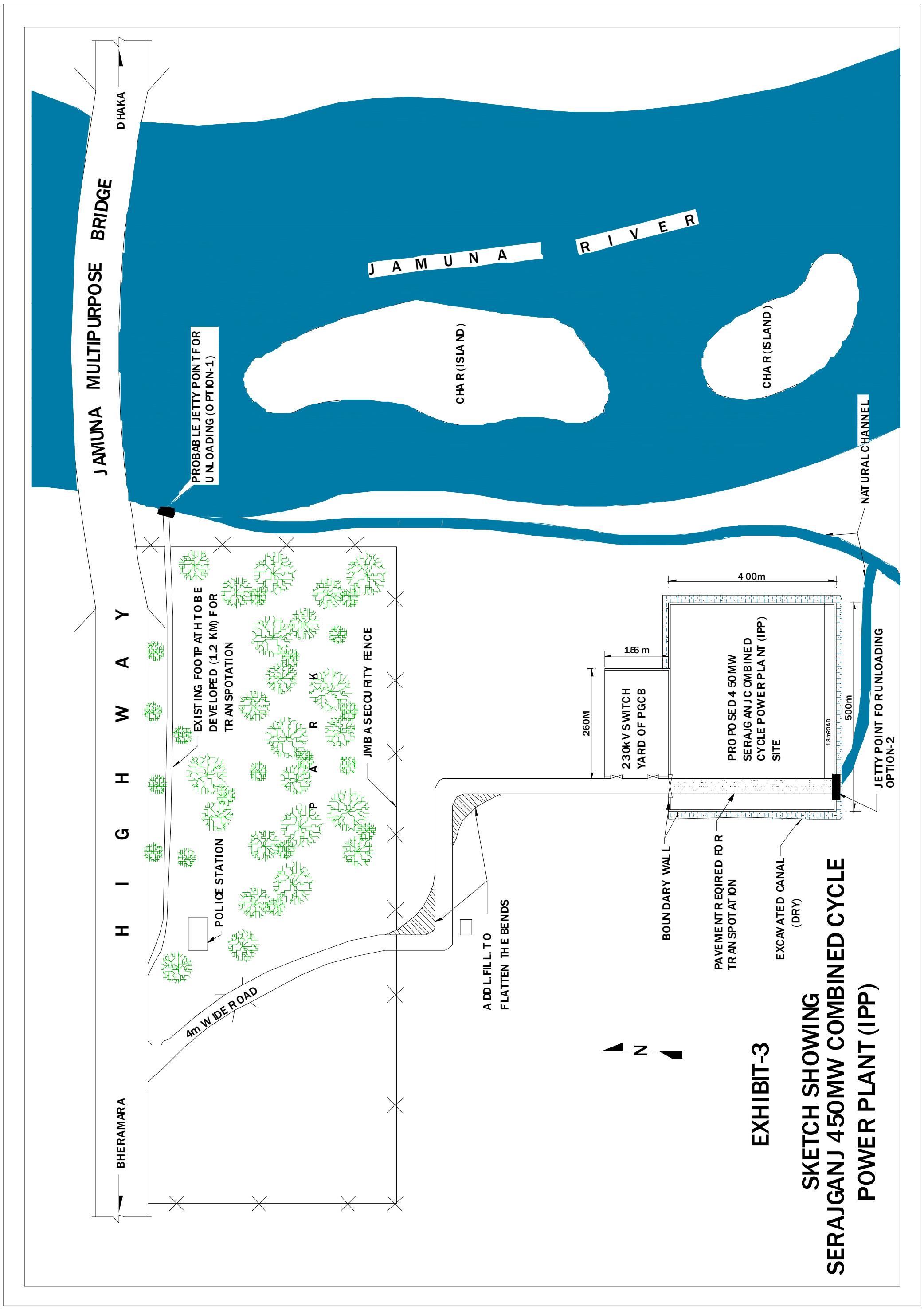


Figure I-4-8-3 Candidate jetty positions in Sirajganj site

Photographs of the candidate positions at Sirajganj site are shown in Photograph I-4-8-3 and Photograph I-4-9-4.

Photograph I-4-8-3 Natural channel near South boundary wall (dry) on May 29, 2008

Photograph I-4-8-4 Excavated canal outside south boundary wall

2) Sirajganj to Bheramara site (overland transportation)
There is a two lane national highway from Sirajganj to Bheramara site.
Brief summary is as indicated below.

- Route length is 113 km.
- Road width is from 5.49 m to 10.06 m, width of shoulder is 0.61 m to 1.86 m.
- Condition of road from Sirajganj site to Bheramara site is good except 7 km (from 41 km to 48 km) from Sirajganj which is partly damaged.
- There are 20 overhead obstructions in this road of which height ranges from 6.1 m to 14.57 m.
- There are 21 bridges, 18 culverts in this road. Longest bridge in this road is the Lalon Shah Bridges over Padma river downstream of Hardinge Bridge. Lalon Shah Bridge is 1.8 km long and 4.57m wide.
- There is an old RCC bridge at 20 km from Sirajganj. This bridge is 51.83 m long and 6.86 m wide and appears to be weak. Other bridges and culverts are good condition.

These overhead obstructions, toll plaza, railway crossing, bridges and culverts etc. can pass cargoes within transportation limitation without repair and renovation of roads, turning point, bridges, culverts except for one culvert, overhead walkway, signal and installation of bypass road, traffic restriction.
Photographs from Sirajganj site to Bheramara site are shown in Photograph I-4-8-5 and Photograph I-4-8-6.

Photograph I-4-8-5 Hatikumrul at 20 km crossing from Sirajganj

Photograph I-4-8-6 Weak RCC Bridge at 20 km from Sirajganj

(3) Mongla port to Bheramara site(overland transportation)
There is a two lane national highway from Mongla port to Bheramara.
Brief summary is as indicated below.

- Distance between Mongla port and Bheramara site is 226 km.
- Entire road is built of asphalt concrete. Road width is 4.5 m to 9.1 m and the either end width of shoulder is 0.61 m to 1.37 m.
- Road condition is good except for partly damaged road to 5 km from Mongla port and there are 128 turning points with 20 to 90 deg.
- There are 70 overhead obstructions in this road of which 69 are overhead power line, one over head dish line, height ranges from 3.5 m to 9.17 m.
- Height of one toll plaza is 14.57 m.
- There are nine railway crossing.
- There are 29 bridges and 75 culverts in this road. Longest bridge in this road is the Khan Jahan Ali Bridge over the river Rupsha near Khulna town. Khan Jahan Ali Bridge is 1.36 km long and 16.65 m wide. Khan Jahan Ali Bridge is a new bridge constructed with the assistance of JICA. Condition of other bridges and culverts except for two small culverts are good.
- There are two small culverts at 26 km and 28 km from Bheramara. Width of these two culverts is only 3.84 m.

These overhead obstructions, toll plaza, railway crossing, bridges and culverts etc. can pass cargoes within transportation limitation without repair and renovation of roads, turning point, bridges, culverts except for two culverts, overhead walkway, signal and installation of bypass road, traffic restriction.
Photographs of overland transportation from Mongla port to Bheramara site are shown in Photograph I-4-8-7 to Photograph I-4-8-10.

Photograph I-4-8-7 Mongla Port Road at 81km from Mongla Port

Photograph I-4-8-8 Rail Crossing

Photograph I-4-8-9 RCC Bridge at 157km from Mongla Port

Photograph I-4-8-10 Khulna-Chuadanga turning at 197km from Mongla Port

(4) Comparison of transportation cost

Comparison of transportation cost is shown in Table I-4-8-9.

Cargoes except for heavy weight cargoes were transported by overland transportation from Mongla port to Bheramara site.

Channel transportation period for route 2 via Sirajiganj was restricted within 3 months from July to September and the period is same as direct channel transportation route from Mongla port to Bheramara site as indicated in above item (3). The channel condition from Daulatdia to Sirajganj is same condition from Daulatdia to Bheramara site on available period for channel transportation and can not navigate through the year; therefore this channel route from Daulatdia to Sirajganj has no merit. The route from Mongla port to Bheramara site via Sirajganj site was dropped from cost evaluation.

Route 3 does not include the repair and renovation cost for road, bridges and culverts, bypass road etc.

The transportation cost in route 1 is economic compared with route 3.

Table I-4-8-9 Comparison of Transportation Cost

SUMMARY OF COST ESTIMATE

Sl	Item	Route 1	Route 3
1.0	Public Expenses	3,624,575.14	2,266,234.10
1.1	Port Charges	2,266,234.10	2,266,234.10
1.2	Line Expenses	1,200,000.00	
1.3	Canal Charges	23,341.04	
1.4	Pilotage	135,000.00	
2.0	Overland Transportation Cost		
2.1	Mongla Port to Bheramara (light lift cargoes)	16,418,000.00	16,418,000.00
2.2	Mongla Temp Jetty to Bheramara (heavy lift cargoes)		145,185,000.00
2.3	Serajganj to Bheramara (heavy lift cargoes)		
3.0	Channel Transportation Cost		
3.1	Mongla to Bheramara (heavy lift cargoes)	77,792,000.00	
3.2	Mongla to Serajganj (heavy lift cargoes)		
3.3	Mongla Outer Anchurage to Temp Jetty (all cargoes)		6,127,800.00
4.0	Unloading Cost at Bheramara Jetty	30,000,000.00	
5.0	Cost of development of approach road from Jetty/ Highway to Highway/Jetty		7,500,000.00
6.0	Cost of Temp Jetty at Mongla Port		20,000,000.00
7.0	Cost of Jetty at Serajganj		
8.0	Cost of approach road from highway to project site	12,500,000.00	12,500,000.00
9.0	**Sub-Total (Transportation Equipment)**	**140,334,575.14**	**209,997,034.10**
10	Cost of Transportation of local construction materilas and consumables	63,300,000.00	63,300,000.00
11	**Total Transportation Cost**	**203,634,575.14**	**273,297,034.10**
12	Cost of Jetty at Bheramara	35,000,000.00	
13	Cost of Overland Transportation from Mongla to Bheramara (SL No: 1.1+2.1+8)	31,184,234.10	** 209,997,034.10
14	Cost of Overland Transportation from Sirajganj to Bheramara (SL No: 2.3+5)		
14	Cost of Channel Transportation Mongla to Bheramara (SL No: 1.2+1.3+1.4+3.1+4)	109,150,341.04	
15	Cost of Channel Transportation from Mongla to Sirajganj (SL No: 1.2+1.3+1.4+3.2+7)		

Note1: * Sl No: 1.1+2.1+2.2+3.3+5+6+8

Note2: Route 3 excludes repair and renovation cost of roads, bridges and culverts

4.8.7 Recommended transportation route

Summary of the problems and countermeasures, cost are shown in Table I-4-8-10.
The problems and countermeasures, cost estimation for each transportation route shows route 1 could be recommended as transportation route for heavy weight cargoes.
In this recommendation all heavy weight cargoes shall be shipped to Bheramara site from July to September by adequate numbers of barges and tugboats and also permanent jetty and storage yard for construction etc. at Bheramara site shall be prepared before heavy weight cargoes

transportation starts.

Transportation route	Problems	Countermeasures	cost
Route 1 Heavy weight cargoes : Channel transportation from Mongla port to Bheramara site Note1:HRSG modules are transported by channel. Note2:Cargoes except for heavy weight cargoes are transported by overland transportation.	Necessary channel transportation period is 3 months. This period is same as available channel transportation period.	・Study of overland transportation for HRSG modules to reduce channel transportation risk. Channel transportation period will be reduced to 2 months can be expected. ・Study of overland transportation permission for Heavy weight cargoes over 40 ton.	low
Route 2 Heavy weight cargoes : Channel transportation from Mongla port to Sirajganj and Overland transportation from Mongla port to Bheramara site Note1:HRSG modules are transported by channel. Note2:Cargoes except for heavy weight cargoes are transported by overland transportation.	Channel transportation period is restricted within 3 months same as route 1 and route 2 can not navigate through the year, therefore this route has no merit	This route was dropped from cost evaluation.	
Route 3 All cargoes transportation : Overland transportation from Mongla port to Bheramara site	・Overland transportation for heavy weight cargoes	Careful planning with road administration authority etc. is necessary to obtain the permission of heavy weight cargoes transportation.	high

Note 1: Route 3 does not include repair and renovation cost for roads, bridges, culverts etc. required in overland transportation of heavy weight cargoes.
Note 2 : Overland transportation cost from Mongla port to Bheramara site excluding the repair and renovation cost for roads, bridges, culverts etc. required in overland transportation of heavy weight cargoes is Taka 273,297,034 (USD 3,921,047) as shown in Table I-4-8-9. The unit cost per weight ton is approximately 1000USD. The unit cost per weight ton including the repair and renovation cost for roads, bridges, culverts etc. required in overland transportation of heavy weight cargoes as described in section 4.8.3 is approximately 1 million USD. The unit cost per weight ton of cargo is approximately ten thousand USD. This means the overland transportation

of heavy weight cargoes is almost the repair and renovation cost for roads, bridges, culverts etc.. Estimated cost of overland transportation from Mongla port to Bheramara site including the repair and renovation cost for roads, bridges, culverts etc. required in overland transportation of heavy weight cargoes based on this unit cost of ten thousand USD per ton weight of cargo is approximately 45 million USD. The estimation cost of this project increases moreover because the total overland transportation distance in Mymenshingh and in this project is 145 km and 226 km respectively.

4.8.8 Heavy weight cargoes transportation method for maintenance

Periodic maintenance for gas turbine combustors and rotor vanes, the compressor rotor vanes are necessary. Transportation method for these parts shall be clarified after plant completion. The weight and size of these parts is within the limit of overland transportation. Usually these parts can be transported by trucks or trailers without permission of road administrator.
On the other hand gas turbine rotor is not need periodic maintenance but has possibility the maintenance or repair needs in duration of 30 years plant life. Channel transportation for this part will be possible from July to September to be constructed jetty as permanent facility in Bheramara site but limited from July to September.
In this project EPC contractor shall study the overland transportation method with the permission of road administrator for the heavy weight cargoes such as existing Mymenshingh CCPP.
Careful planning including cargo weight and size transported, applied trailers, transportation routes and period, time, strength check of road, bridges and culverts, the reinforcement check, bypass route check etc. with road administrator and authorities concerned such as BIWTA is necessary to obtain the permission of heavy weight cargoes for overland transportation.

4.9 Project Implementation Schedule

4.9.1 General

Based on the notices from MoPEMR on August 31, 2008 that the natural gas supply to Bheramara power plant could be around 2016, the new strategy which natural gas could be supplied by 2016 is identified.
Meanwhile, since Bangladesh faces a serious power shortage, BPDB would like to construct new large-scale power plants as soon as possible to cope with such situation.
Therefore, taking into account of a delay of gas supply, and measures to severe power shortages and various issues related to power plant construction, the goal of completion of Bheramara combined-cycle power plant should be the end of September in 2014.

4.9.2 Project Implementation Schedule

Initially, though Bheramara combined-cycle power plant will be completed upon at the end of 2012 based on request from the Bangladesh side, the goal for putting into commercial operation of Bheramara CCPP will be the end of September 2014 which is more realistic, and as soon as possible due to delay in gas supply.
The followings are assumed to be critical points to be considered in developing the project schedule.

(1) Heavy cargos having a weight of more than 40 tons are transported on channel Mongla port to Bheramara site. But, channel transportation is limited from July to September because water depth in Padma river is not enough to move barge loading such heavy cargo.

(2) In recent years, since global demand for F-type gas turbine is high, the plant's production lines of four major gas turbine manufactures (GE, Mitsubishi, Alstom, Siemens) are occupied, the required delivery period from design to FOB of gas turbines take about 25 months.

Project schedule is made taking into consideration the above issues and show in Table I-4-9-1 and Figure I-4-9-1.

1) JICA standard

Period when requires the selection of consultant and the manufacturers is JICA''s standard. In this case, since the gas turbine will be arrived at Mongla port on July or later after the FOB, through maritime transportation in Bangladesh, the gas turbine has to be waiting to transport on channel transportation for nine months. So, this is inefficient work.

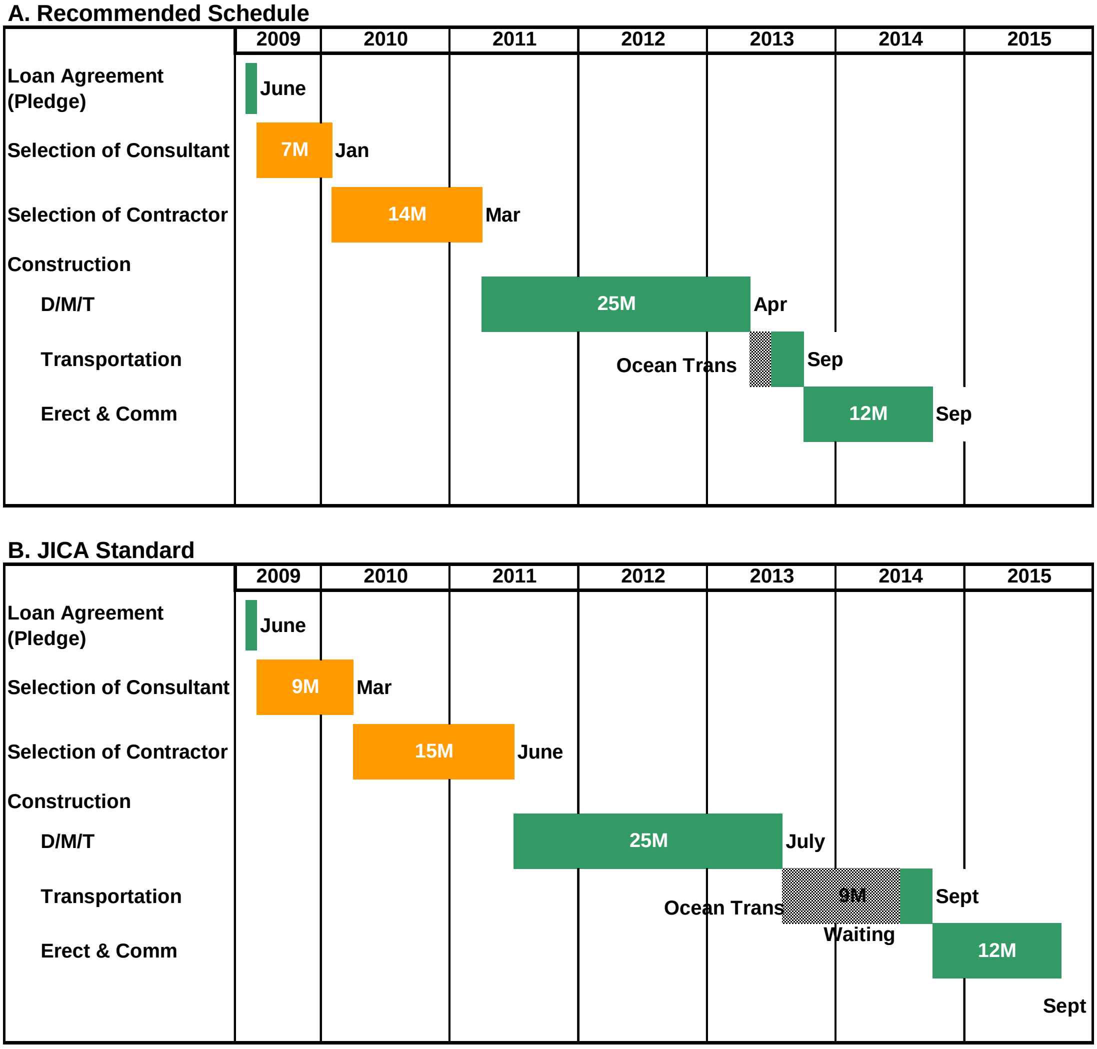
2) Recommended schedule

This schedule is made to shorten each one (1) month of the selection of consultants and manufacturers for arriving gas turbines and other heavy cargos at Mongla port before July.

Table I-4-9-1 Required Months from Selection of Consultant to the Completion of CCPP

	Selection of Consultant	Selection of Contractor	Construction Period				
			*1	*2		*3	Total
				Wait	Trans		
JICA Standard	9M	15M	25M	9M	5 M	12 M	51M
Recommended	7M	14M	25M	0M	5 M	12 M	42M

Remarks：*1 Design and Manufacturing、*2 Transportation、*3 Erection and Commissioning



Remarks : D/M/T - Design, Manufacturing and Test

Figure I-4-9-1 Project Schedule

4.10 Outline of Long Term Service Agreement for Gas Turbine

(1) Maintenance of Gas Turbine

Major equipments of CCPP are gas turbine, HRSG, steam turbine, generator and son on. Generally gas turbine has the most frequent failure in such major equipments. Therefore the maintenance quality for the gas turbine makes great influence on the availability of the power plant.

During the operation of the gas turbine, its hot parts such as combustor, turbine blade are exposed high temperature gas over 1,000°C. Consequently the degradation / damage of blades are more severe than those of steam turbine and it is required more frequent interval for inspection / repair / replacement. The expected life of those hot parts of gas turbine is specified by the original equipment manufacture (OEM) and the specified inspection / repair are required up to the life end. Table I-4-10-1 shows an example of the inspection interval. Generally there are three type of the inspection according to the equivalent operating hour[5].

[5] The adjusted operating hour which is added the influence of start up, shut down, trip etc on actual

Table I-4-10-1 An Example of Inspection Interval

Type of Inspection	Inspection Interval / Equivalent Operating Hour
Combustor Inspection	8,000 hr
Turbine Inspection	16,000 hr
Major Inspection	48,000 hr

The hot parts are made from super alloy whose base metals are nickel and cobalt. For the repair of the hot parts needs special technique and facilities for welding, coating etc. Therefore most users order those repair to the OEMs or some repair company.

(2) Characteristic of Long Term Service Agreement for Gas Turbine

As described above hot parts require periodical inspection / repair / replacement. Consequently gas turbine OEM, such as GE, offers the Long Term Service Agreement (LTSA) which covers such inspection / repair / replacement for certain period at a lump sum fee. This LTSA is going to be a major contractual framework for operating CCPP. The contract period is usually 6 years or 12 years considering the major inspection will be implemented for every 6 years.

Table I-4-10-2 shows characteristic of LTSA. Without LTSA, the users carry out inspection / repair / replacement of hot parts by themselves according to their monitoring of operating hour, start up times and trip times. In case of LTSA, it is included in the service provided in LTSA. Additionally to support such service the remote monitoring system is introduced and by this system operating condition of the plant can be monitored at the monitoring center of the service provider in real time. Introducing such system together with dispatching a resident engineer contributes to improve availability by monitoring sign of a trouble and by prompt measure for a trouble. As option, a service provider offers availability guarantee because he can monitor operating condition of gas turbine and carried out maintenance by himself.

Another major feature of LTSA is that the fee of inspection / repair / replacement is paid by lump sum. The price of LTSA is almost same or lower than sum of individual price for inspection / repair / replacement. Considering there are some additional services such as a remote monitoring system, the price of LTSA would be attractive. And furthermore, as the price of LTSA is fixed lump sum fee at the signing of the contract, the user can hedge a risk of cost over by unexpected repair and replacement of the expensive hot parts after commencement of the contract.

When a user implements repair / replacement individually without LTSA, there is huge variation of annual maintenance budget between in the year required a lot of replacement and in the year not required so much replacement (about 10 million USD per one F class gas turbine.) Such huge variation of expenditure makes great influence on the management of the small power producer like IPP. On the other hand, LTSA's payment is fixed monthly fee based on lump sum price which contributes stability of management of the user.

---

operating hours.

Table I-4-10-2 Characteristic of LTSA

	With LTSA	Without LTSA
Hot Parts Management (inspection / repair / replacement)	Service provider	User
Monitoring of gas turbine operation	Additionally, service provider cans it by the remote monitoring system. It contributes improvement of availability.	Only user does it.
Resident Engineer of OEM	Included.	No service.
Availability Guarantee	Possible as option.	No service.
Payment Schedule	Fixed monthly fee based on lump sum price. The price of LTSA is almost same or lower than sum of individual price for inspection / repair / replacement. User can hedge a risk of cost over by unexpected repair and replacement of the expensive hot parts. (other than the reason attributed to user)	User pays individual inspection / repair / replacement. User has to pay cost over by unexpected repair and replacement of the expensive hot parts.

(3) Application to the Project

Bheramara CCPP will be NWPGCL's first F class CCPP. And NWPGCL is planning more efficient management of power plants by smaller organization than that of BPDB. Therefore LTSA is necessary technical support for stable operation of CCPP. And furthermore from economical point of view, LTSA offers attractive price rather than sum of individual price and the fixed fee by LTSA contributes on stable cash flow of NWPGCL.

The Bheramra Project is planning to implement by financial support of Japanese ODA Loan. As the first attempt that LTSA was evaluated as the scope of the Japanese ODA Loan project was Haripur CCPP Project, for which Japanese Government and Bangladesh Government exchanged note to provide Japanese ODA Loan in December 2007. LTSA is also preferable contract scheme from lenders position because LTSA contributes on both stable operation of the Plant and stable management of NWPGCL as mentioned above. Therefore it is recommended that LTSA is introduced as the scope of the Bheramra project.

4.11 Project Implementation Organization

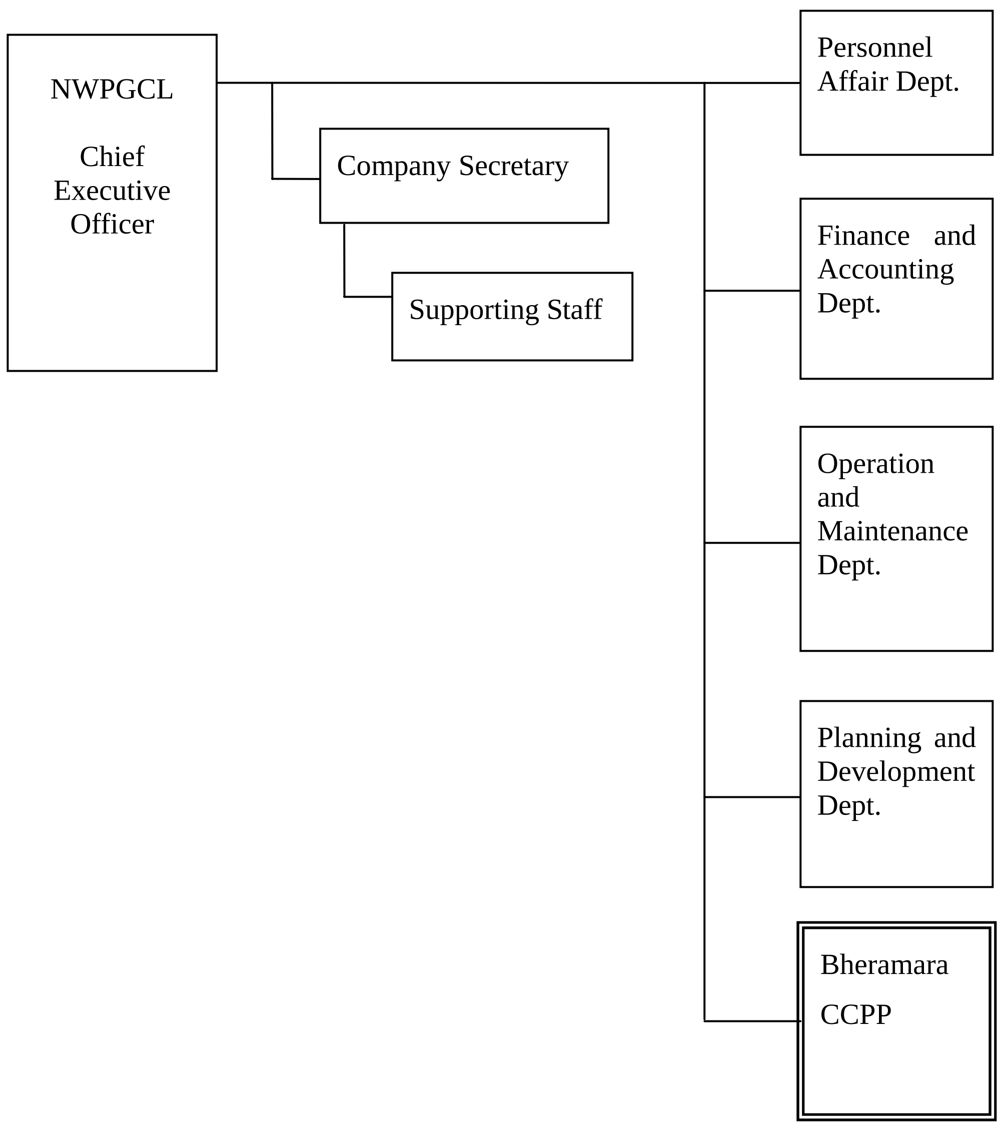
4.11.1 General

This section mentions an implementation organization which implement Bheramara CCPP project. It is recommendable that a Project Implementation Unit (hereinafter call as "PIU") will be established to manage and implement Bhearamara CCPP project as a department in North

West Power Generation Company Limited (NWPGCL).
And personnel and staffs belonged to PIU will be shifted to Bheramara CCPP or O&M department of NWPGCL.
Concerning transmission line and substation, NWPGCL will assign all the responsibility to this project.. Supervisor will be sent from PGCB to NWPGCL at the Construction stage. 230kV TL/SS and 132kV SS will be transferred to PGCB alongwith equipment and loan after the completion of the construction work. Project Director of Bheramara Project will check and sign a progress report at each milestone from design stage to completion for confirming progress and each responsibility of this project.

4.11.2 Organization of NWPGCL

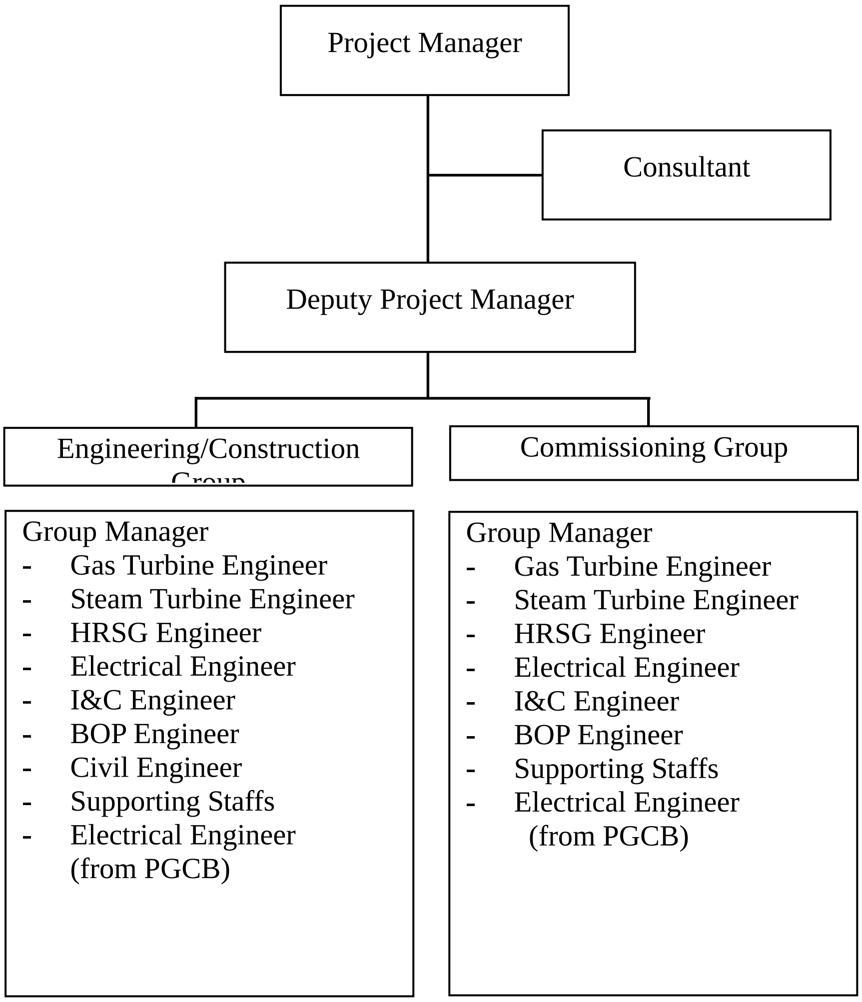
(1) Establishment of Project Implementation Unit (PIU)
The organization of NWPGCL proposes the organization as shown in the below and installs Project Implementation Unit (PIU) in CEO's falling plumb down. PIU plays the central role of implementation of this project.



(2) Organization of PIU

PIU consists of Project Manager. Deputy Project Manager and 2 sections of Engineering/Construction Group and Commissioning Group, and a Consultant as an adviser. Taking the establishment of NWPGCL as an opportunity, it seems important to establish an organization which is slims to take a quick and flexible action and handover a right certain degree (for example, Project Manager has a right to purchase goods under 1 Mil.US$) to Project Manager in PIU.

1) Organization of PIU



2) The role of PIU and engagement period

Phases	Engineering Phase	Construction Phase	Commissioning Phase	Remarks Position after taking over
Project Manager (P/M)	━━━	━━━	━━━	Superintendent of Bheramara CCPP
Deputy P/M	━━━	━━━	━━━	Vice Superintendent of Bheramara CCPP
Engineering/ Construction Group				
Group Manager	━━━	━━━	━━━	All personnel's will shift to O&M sections in CCPP. Capacity building will be carried out to assign the main post (Head of department or chief of section) Or NWPGCL will employ the personnel who has a capability to achieve the works
Gas Turbine Engineer	━━━	━━━	━━━	
Steam Turbine Engineer	━━━	━━━	━━━	
HRSG Engineer	━━━	━━━	━━━	
Electrical Engineer	━━━	━━━	━━━	
I&C Engineer	━━━	━━━	━━━	
BOP Engineer	━━━	━━━	━━━	
Civil Engineer	━━━	━━━		
Electrical Engineer (from PGCB)	━━━	━━━	━━━	transmission line and substation
Commissioning Group				
Group Manager		━━━	━━━	All personnel's will shift to operation sections in CCPP after CCPP taking over.
Gas Turbine Engineer		━━━	━━━	
Steam Turbine Engineer		━━━	━━━	
HRSG Engineer		━━━	━━━	
Electrical Engineer		━━━	━━━	
I&C Engineer		━━━	━━━	
BOP Engineer		━━━	━━━	
Electrical Engineer (from PGCB)		━━━	━━━	transmission line and substation
Number of Employee [NWPGCL permanent personnel]	11	19	18	

4.12 Conclusion

4.12.1 Evaluation

As a result of having examined a technical feasibility of the construction plan, that is, power demand forecast, beneficial effect, power supply development program, a power system plan, a fuel supply plan, the site situation, examination of generation facilities basics method, erection and transportation of equipment and materials, the implementation organization, a project schedule, a gas turbine long term service agreement, it is almost judged that a construction plan of a Bheramara CCPP project is almost justified. But a trend of gas supply should be carefully monitored in future.

4.12.2 Confirmation of Technical Feasibility

(1) Power Demand Forecast

A demand for demand assumption PSMP2006 assumption was similar with a demand assumption in 2005 PSMP1995, ADB Gas Development Project, Gas Sector Master Plan, and it was confirmed that I was proper.

(2) Beneficial Effect

It was confirmed that beneficial effect such as electrification rate improvement in western areas, promotion of the employment, improvement of life of inhabitants in western area was big by constructing Bheramara CCPP.

(3) Power System Plan

It was confirmed that East-West electricity supply-demand balance and a voltage descent in western part area would be improved by Bheramara CCPP.

(4) Fuel Supply Plan

As for natural gas supply, construction of gas pipelines by support of ADB from eastern part gas field to Khulna of the western part was performed, and the infrastructure which related to gas supply was got ready steadily, but a delay of development of a gas field, gas production and decrease of a supply came to the front and became opaque whether gas supply was done in the appropriate time to the power stations in the future concerned.

However, secretary of power division of MoPEMR thinks that the gas supply to Bheramara CCPP was found for the time being by having promised definitely that it supplies gas in Bheramara CCPP heat with precedence in 2014.

(5) Cooling System

There are three (3) cooling system to cool the exhaust steam from steam turbine. Those are a direct cooling method by river water, a cooling tower method and an air cooled condenser. As a result of examining them from technical, environmental and economical point of view, a cooling tower method is employed. In the case of a cooling tower method, underground water is used for makeup water for cooling tower. As a result of investigating aquaire of underground water and analyzing influence on the existing tube wells by taking large quantity of underground water, no influence is found.

However, NWPGCL has to monitor underground water level of the existing tube wells if the existing tube wells will dry up and cope with recovery of water quickly

(6) Study on Selection of Combined Cycle Power Plant

It was confirmed natural gas is advantageous for F type gas turbine from technical, economical and environmental point of views. Multi-shaft type combined cycle power plant is suitable for Bheramara CCPP from the situation of an electric power system of Bangladesh.

(7) Equipment and material Transportation

Heavy cargos are planed to transport from Mongla port to Bheramara site by channel. But the period of channel transportation is limited to three (3) months from July to September because the depth of Padma River is not enough to travel a barge ship loaded heavy cargo. So, risk in channel transportation should be avoided by shifting heavy cargos to road transportation.

(8) Implementation Organization

When NWPGCL will be separated from BPDB, PIU who implements the project should be established in NWPGCL and will promote smooth project management by transferring right as much as possible.

(9) Project Schedule

At present, it seems that it is justified that Bheramara CCPP will put into operation at the end of September 2014 taking into consideration prediction of gas supply, a transportation period of heavy goods, and the appointed date of delivery of a gas turbine. However, it seems that a review will be necessary appropriately in future because I receive economy slump to do a financial crisis in U.S.A. of these days in the beginning as well as a delay of gas supply, and shortening on the appointed date of delivery by decrease of volume of production of a gas turbine is thought about.

(10) Outline of Gas Turbine Long Term Service Agreement

Since a gas turbine adopted in the Project is a most modern type, it is difficult to carry out maintenance of hot parts such as combustor, blades and buckets by personnel of power plant themselves. Therefore, it is necessary to contact a gas turbine long term service agreement with gas turbine manufacturer.