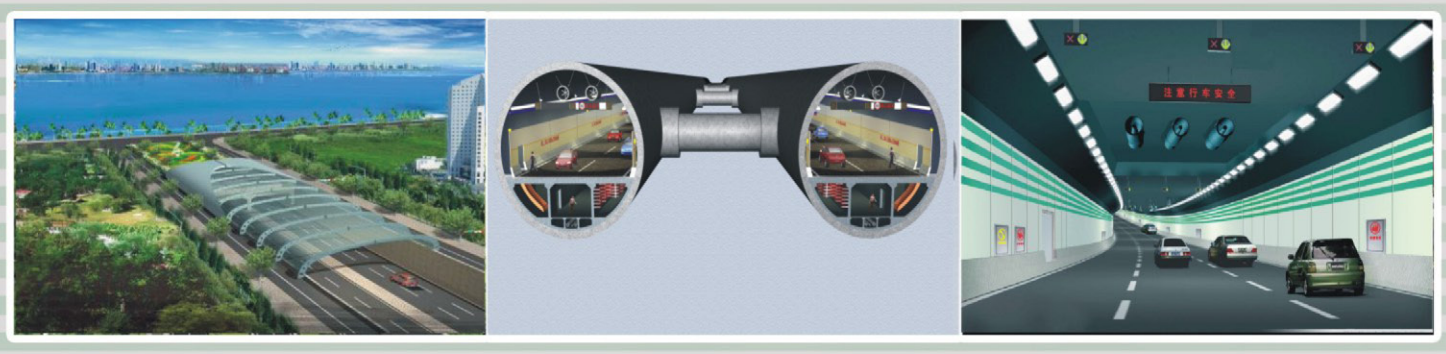
Bangladesh Bridge Authority

Feasibility Study for Multi-lane Road Tunnel under the River Karnaphuli, Chittagong, Bangladesh

Final Report

Volume I of II Executive Summary

April 2013



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CHINA COMMUNICATIONS CONSTRUCTION COMPANY Ltd.

ARUP Ove Arup & Partners Hong Kong Ltd

Bangladesh Bridge Authority

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Volume I of II : Executive Summary

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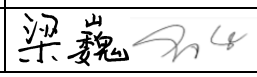
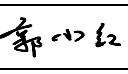
		Signature			
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Contents

SUMMARY

The Karnaphuli River divides Chittagong District into two parts. One part is confined with the city and the port, the other part is the area of heavy industry. Current two bridges are not sufficient to accommodate the existing and increasing huge traffic flow. Due to river morphology, siltation on the bed of the Karnaphuli River is a big problem and the major threat for proper functioning of the Chittagong Port. To face the problem on siltation, Bangladesh government intends to construct a tunnel crossing the Karnaphuli River instead of another bridge over the same river. Bangladesh Bridge Authority (BBA) was entrusted to implement the project. China Communication Construction Company Ltd joint ventured with Ove Arup & Partners Hong Kong Ltd (CCCC-Arup JV) was appointed to carry out the feasibility study.

The focus of the project is to carry out detailed economic and engineering investigation to examine economic viability and technical feasibility for construction of tunnel under the Karnaphuli River.

Based on the traffic survey, analysis and forecast, demonstrated by expressway service level analysis, dual-two lanes expressway standard with design speed of v=80km/h is recommended for Alignment C with considerations of road network plan, traffic volume forecast, overall transportation system, and long-term development of the project area.

Based on site visits and data collected, several alignment options proposed are analyzed, compared, and screened. Three alignment options, namely A, B, and C are finally studied in details. After comprehensive analysis and comparison, considering service function, traffic function, construction scale, construction risk and construction cost and etc., Alignment C is recommended. The principal part of Alignment C adopts the expressway standard and the approach road adopts the urban trunk road functions, both of them are dual-two lanes with design speed of 80km/h. Alignment C is located at the estuary in Chittagong suburb with good construction conditions. The tunnel with this alignment will provide strong service function for transit traffic, which will play an important role in relieving traffic pressure of existing bridges, promoting regional economic construction, and enhancing joint development of regional economy; meanwhile, it will provide convenient transport conditions for the planned Deep Sea Port in south Bangladesh, thus exerting a significant role in promoting the development of transportation industry in Bangladesh and improving the state highway network.

The topographic and bathymetric survey, geological and geotechnical investigation, hydrological survey indicated that Alignment C is technically feasible.

Based on the results of traffic survey, analysis and forecast, topographic and bathymetric survey, geological and geotechnical investigation, hydrological survey, a preliminary design of the tunnel is made following the international standards and codes (US, BS, China et al):

- Dual two-lane tunnel design without non-motorized vehicle lane and sidewalk is recommended.
- Cross section type of twin-tube dual two-lane is recommended.

- Through comprehensive comparison among the various tunnel construction methods suitable for this project, shield-driven method is recommended for tunnel construction.
- Design for major technical parameters of shield segment is made. The segment for shield tunnel is 10.8m in diameter, 0.5m in thickness and 2m in ring width. Common segment with taperness of 36mm is adopted. The segment separation adopts the pattern of 5+2+1, i.e. total 8 pieces, including 5 standard pieces, 2 adjacent pieces and 1 capping piece. Both ring and longitudinal joints of segments adopt inclined bolt connections.
- Various excavation and lateral support systems for bank side sections and working shafts are compared and analysed. Sheet pile, SMW pile construction method, bored cast-in-place pile and diaphragm wall are adopted respectively corresponding to different excavation depths.
- According to structure stress and concrete durability design requirements, different construction materials and dimensions of main structures are also considered.
- Preliminary study on waterproofing structure of shield segments and bank side section structures is also made.

Based on the quantity from preliminary tunnel design and unit rates of labour, machinery and material in local market and international market, construction cost, maintenance cost and operation cost of Alignment C is analysed.

- Total length of the tunnel and link road is about 9.092 km. Total project cost is about USD 674.91million, or equivalent to USD 74.23 million per km.
- The operation cost is estimated to be as BDT 171,620,000/year according to the price level in 2012.
- The daily maintenance cost for traffic engineering (including tunnel electrical and mechanical equipment, road electrical and mechanical equipment, and traffic security facilities) is USD 1,800,000/year (price in July 2012), with inflation rate of 5% per year. Regular maintenance cost is USD 1,900,000 every five years (price in July 2012), with inflation rate of 5% per year.

The Environmental Impact Assessment is a legal requirement for obtaining Environmental Clearance Certificate from the Department of Environment (DoE) for implementation of proposed Multilane Tunnel Project at Patenga-KAFCO end under river Karnaphuli. The information and data presented in the report are based upon the preliminary tunnel design documents, and some specific data obtained and gathered from relevant organizations/institutions, field survey and public consultation meetings in the study area in line with the Environmental Guidelines, (Volume 1) published by RHD as well as the EIA guidelines for industries published by DOE of the GoB.

- Construction work, including tunnel construction, will generate a number of negative impacts on the environment. Many of the impacts during the construction period for project cannot be assessed at this moment, because sites for temporary work activities have not been identified and/or information concerning the period and the duration of these activities are

not available. The temporary construction works could create more impacts than the activities related to the permanent works. For this reason, environmental management and monitoring program is developed for both temporary and permanent works covering preconstruction, construction and operation stages.

- The key impacts which were identified and addressed in the Environmental Impact Assessment report are land loss, involuntary resettlement, spoil waste, air and noise quality, disturbance during construction, construction pollution, management of the construction workforce and workers health and safety, management of accidents and emergencies.
- As the proposed tunnel location is exposed to Bay of Bengal, there is a possibility of tidal water flooding due to global warming and sea level rise. Climate change considerations will play a crucial role in the design of tunnel and its components.
- Implementation of appropriate Environmental Management Plan (EMP) and mitigation measures during various phases will minimize the negative impacts of the project to acceptable levels. To ensure that these plans and mitigation measures are implemented and negative impacts are avoided, the EMP will be included in the contract documents of the Project with a separate line item on environmental management in the bills-of-quantities.
- Since the project sponsors show positive approaches towards environmental management and safety standard more in-line with their environmental policy and management plan, it is expected that the BBA will provide necessary resources along with Safeguard Division like proper technical personnel with monitoring equipment to make accountable and responsible system for successful implementation of the recommended EMP recorded in the EIA Study.
- Necessary environmental clearance should be obtained for the project before start of construction work. As this EIA has been prepared during feasibility study, this will be further updated during the detailed design stage based on the detailed engineering designs.
- All potential environmental impacts have been reviewed, if the recommended mitigative measures as per this Environment and Social Management Plan (ESMP) is strictly followed, the proposed Multilane Tunnel under the river Karnaphuli project is expected to proceed without having unacceptable environmental effects.

The assessment on resettlement requirements and preparation of action plan has been prepared. The proposed acquisition will eventually relocate households, commercial premises and common property resources for both titled and non-titled. The Resettlement Action Plan (RAP) covers compensation and assistance for resettlement and rehabilitation of Affected Persons (APs) including alternative sites, where feasible, for relocation of the housing, business structures and Common Property Resources (CPRs). Detailed RAP including disclosure and public consultation, relocation resettlement and income restoration, implementation arrangements, resettlement and compensation costs and budgets, RAP implementation schedule, grievance redress mechanism as well as monitoring and evaluation have been elaborated in the report.

The land acquisition plan has been prepared based on the drawing and report of preliminary tunnel design. The proposed land acquisition for the project will cause relocation of households, shops and common properties such as mosque, cremation ground, etc. which is very much sensitive and there are bars in acquisition of such common properties. The project authority should take care of these common properties and take mitigation measures during preparation of the land acquisition proposal as suggested in this document.

A range of social and economic benefits are expected to result from the tunnel including:

- Better connectivity with the proposed industrial developments located east of the Karnaphuli River and the existing port, airport and CBD to the west;
- Reduced congestion in the CBD and on existing bridges;
- Shorter journey times and travel time savings;
- Better utilisation of land east of the river for manufacturing and generating additional value added contributions to the national economy as a result of better labour mobility, and the ability to efficiently move raw materials and completed products via the airport and port;
- Direct connectivity with the New Deep Sea Port to be developed in Sonadia Island and catering to the additional traffic;
- Creation of synergies between the port and airport and existing and proposed tourism assets in Parkir Char east along the river and South Patenga west along the river;
- Improved emergency response in the east area and the western sections of Patiya.

The results of the economic analysis indicate that the project is economically viable under various real discount rates and a summary is provided in the following table.

Items	Undiscounted	Discounted @ 5%	Discounted @ 9%	Discounted @ 12%
NPV	**7,254.0**	**1,528.5**	**465.9**	**150.2**
Economic Internal Rate of Return	**N/A**	**14.7%**	**14.7%**	**14.7%**
Benefit- Cost Ratio	**N/A**	**4.1**	**2.0**	**1.4**

Economic Analysis Summary Results (US$ Million)

Notes: Based on 50 year assessment period

The preliminary findings of the financial analysis indicate that under the assumptions adopted, the tunnel, inclusive of toll revenues is not financially viable without government support. In summary, the key outcomes are:

- **Without Financing Costs** - The funding gap under Option 1 (Public Sector Comparator exclusive of financing costs) is estimated at US$ 275 million.
- **With Financing Costs** - Depending on the chosen financing option, the funding gap ranges from US$ 305 million to US$ 341 million.
- **Interest Rate** - Sensitivity tests using higher interest rates shows the funding gap ranges from US$ 325 to US$ 661 depending on the financing option.
- **Toll and Traffic Demand** - Sensitivity test around lower toll and traffic demand show that the funding gap ranges from US$ 349 to US$ 419 million depending on the financing option.
- **Capital Cost Escalation** - Sensitivity tests around higher capital costs show the funding gap ranges between US$ 395 million to US$ 478 million depending on the financing option.
- **Concession Period –** Sensitivity test around extending the concession period from 30 years to 40 years shows the funding gap ranges from US$ 183 million to US$ 246 million depending on the financing option.
- **Soft Loan** – Sensitivity test around lower interest rates and longer repayment period provided by Donor Institutions show that the project is potentially financially viable under the financing option of 100% loan and at an interest rate of 5% or less with an extended repayment period.

The Bangladesh Bridge Authority will need to seek ways to meet this funding gap. There are a number of options including:

- A capital grant from the Bangladesh Government.
- Seeking soft or concessionary loans from Donor Institutions with extended grace periods and favourable tenor conditions to minimise the debt service burden.
- Using other incentive methods to entice potential investors such as land development rights.
- Exploring other revenue streams such as indirect taxes.

Each of these options could be considered individually however it is likely that a combination of options will be required to provide the best solution.

The financial model of the Karnaphuli River Road Tunnel have been carried out which reveals the project is not commercially viable without Government support. The financial revenue from the project will not provide sufficient return for a private investor to fund the capital cost of construction. The institutional arrangements and financing for operations also suggests possible arrangements while tunnel is in operation stage. The project is anticipated to be divided into packages for construction such that it provides more opportunity for local contractors to be involved in contracts suitable for their skills and experience. Several procurement strategies including Design Bid Build, Early Contractor Involvement and Design & Build have been proposed for different packages in the

river tunnel project in order to optimise the speed, costs and quality of the tunnel. Guidelines for the tunnel during its operation stage and under emergency operations have been included in the Operation and Maintenance (O&M) Plan.

1. INTRODUCTION

1.1 Project Background

Chittagong is the major port city and the gateway of Bangladesh. It is also the second largest city and the "commercial capital" of the country. The Karnaphuli River divides Chittagong City into two parts (**Figure 1.1-1**). One part is confined with the city and the port, the other part is the area of heavy industry. The current two bridges are not sufficient to accommodate the existing and increasing huge traffic flow. Due to river morphology, siltation on the bed of the Karnaphuli River is a big problem and the major threat for proper functioning of the Chittagong Port. To face the problem on siltation, Bangladesh government intends to construct a tunnel crossing the Karnaphuli River instead of another bridge over the same river.

Bangladesh Bridge Authority (BBA) was entrusted to implement the project. China Communication Construction Company Ltd joint ventured with Ove Arup & Partners Hong Kong Ltd (CCCC-Arup JV, the Consultant) was awarded the project on 19th April 2011. Project kick-off meeting was held on 30th May 2011 and a site visit along Karnaphuli River was arranged on 31th May 2011. Meetings with Road and Highway Department and Chittagong Development Authority were held before site visit. The inception report of the project was submitted on 15th June 2011 and approved by the clients on 13th July 2011. The interim report was submitted on 3 November 2011 and approved on 8 April, 2012. The draft final report was submitted on 30 July 2012 and approved on 17 April 2013.

The focus of the project is to carry out detailed economic and engineering investigation to examine the economic viability and technical feasibility for construction of tunnel under the Karnaphuli River.

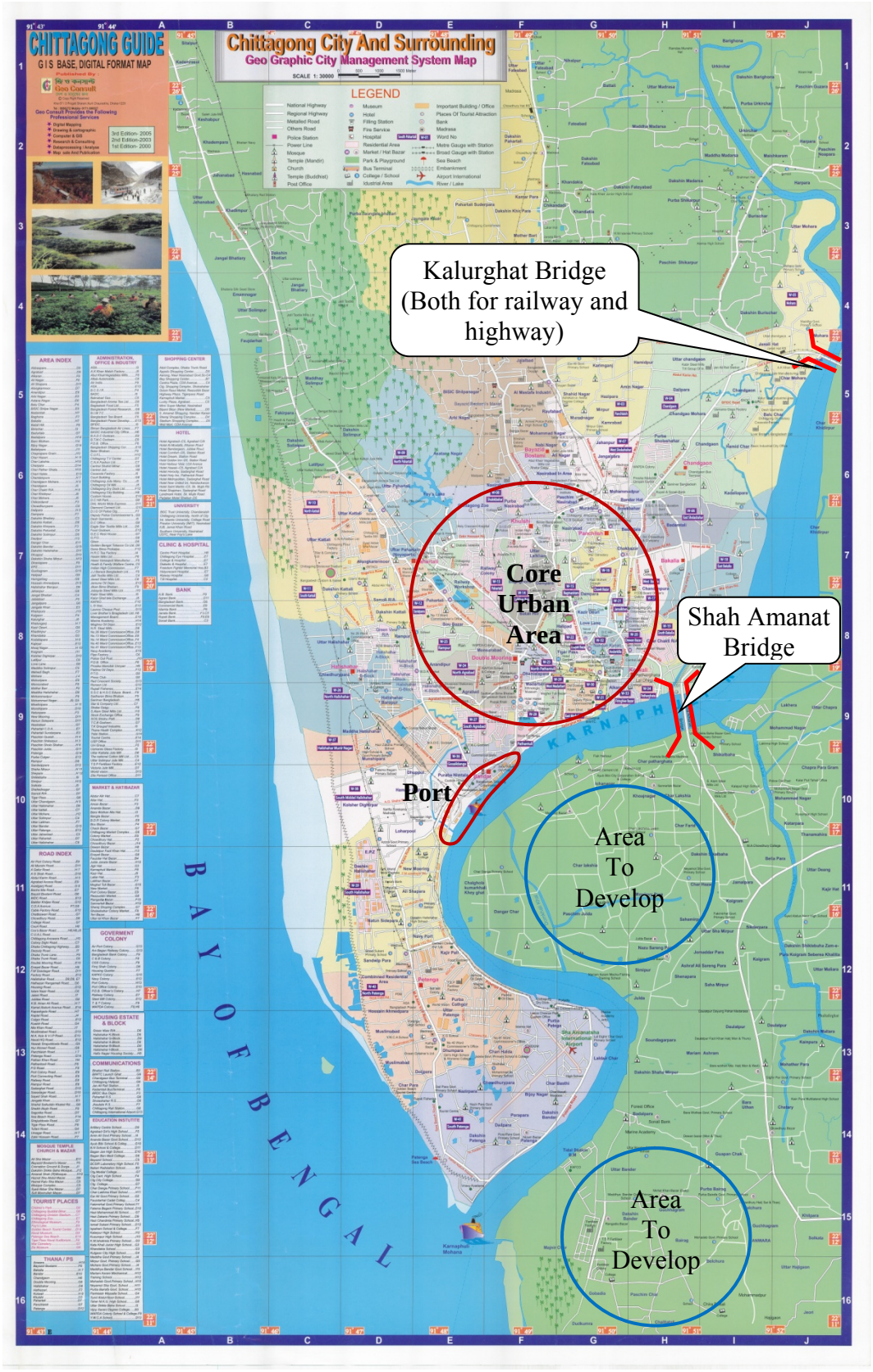


Figure 1.1-1 Karnaphuli River in Chittagong, Bangladesh

1.2 Scope of Services

Services to be provided by the CCCC-Arup JV include feasibility study and preliminary design of multi-lane road tunnel under the River Karnaphuli at Chittagong City (the Assignment). The scope of works is listed below:

a. Optimization of length, location and alignment of the tunnel;

b. Determination of the appropriate tunnel construction method, tunnel configuration and technology;

c. Detailed geotechnical investigations, geological mapping, seismic study, hydrographical survey;

d. Detailed traffic survey with Origin and Destination (O-D) survey, traffic analysis and traffic forecast for a reasonable time horizon establishing traffic model;

e. Detailed environmental impact assessment and environmental management and mitigation plan;

f. Assessment of resettlement requirements and preparation of action plan;

g. Selling out design criteria, preliminary design of the tunnel, approach roads and other components with cost estimation;

h. Preparation of land acquisition plan;

i. Study of socio-economic impacts assessment of the project at local, national and international level;

j. Optimum toll rate determination, detailed economic and financial evaluation determining EIRR, NPV, BCR, FIRR along with sensitivity analysis for different scenarios and toll rates;

k. Assessment of Public Private Partnership possibilities;

l. Formulation of procurement strategy, implementation and Operation and Maintenance (O & M) plan;

m. Preparation of financial model.

1.3 Technical Codes and Standards

Some USA codes will be used for the assignment, which include ACI (American Concrete Institute) codes for concrete design (primarily ACI 318), AISC (American Institute of Steel Construction) codes for steel structure design, ASTM (American Society for Testing and Materials) standards for material and testing requirements, NFPA (National Fire Protection Association) standards for fire & life safety, and etc. The BS codes, Eurocodes, Chinese codes and relevant technical papers will also be referred.

2. SITE CONDITION

2.1 Chittagong District

Chittagong Division is located at the south east of Bangladesh (**Figure 2.1-1**). The Chittagong Division is known for its vast hilly terrain and a tropical monsoon climate with much rainfall each year. Chittagong District and Chittagong City are also shown in the right hand side of the figure. Please note the difference among Chittagong Division, Chittagong District and Chittagong City (Figure 2.1-1). The former includes the latter. Chittagong City only represents the urban area in the western area of the Karnaphuli River.

Chittagong City is the second largest city in Bangladesh which at the same time is the Commercial Capital City of Bangladesh, with a population estimated at over 5.74 million. Chittagong is located at 22°22'0"N, 91°48′0″E, south eastern in Bangladesh and northern on Sitakund, and is seated on the banks of the Karnaphuli River, covering a total area of 168.07 sq km[1].

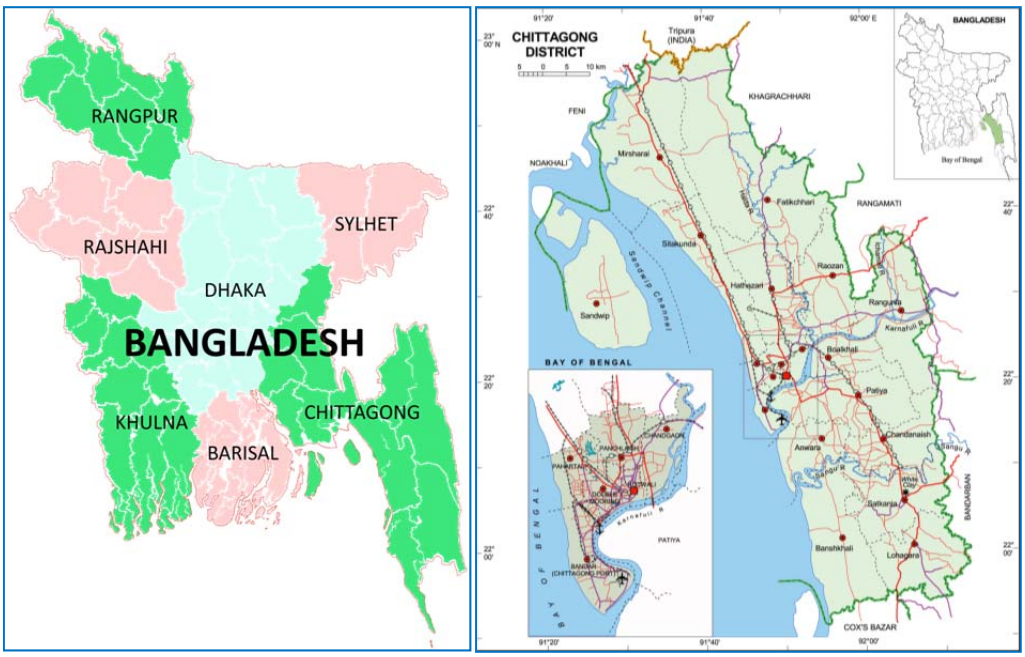


Figure 2.1-1 Bangladesh and Chittagong

Developed rapidly through a market–based economy. Chittagong District, having the largest port of the country, plays an important role in this rapid growth.

The surrounding mountains and rivers make the city attractive as an ideal vacation spot. Transport in Chittagong consists of various bus systems and taxi services. There are also traditional manual rickshaws. Trains and the National Highway connects Chittagong with the Bangladesh cities of Dhaka, Shylhet, Comilla, and Bhairav.

[1] Source: Statistical Yearbook of Bangladesh 2010

2.2 Climate

Provided in the following figures, the temperature of the past ten years in Chittagong City shows an average of over 28°C for over 7 months starting early in April. January carried a coldest average temperature of over 20°C. The mean monthly temperature in each year from 2001 reveal a steady fluctuation of less than 2.5°C to 5°C of difference.

There is a large difference (over 20°C) of the maximum and minimum temperature within each month, especially in January and December, two coldest months in Chittagong. Excluding these two months, which still reach 32°C, the maximum temperature stays constantly above 35°C. On the other hand, the minimum temperature of a month increased gradually to a peak at approximately 24.5°C, after which it declined straight back to 11°C in December, which is about the same level in January.

2.3 Topography

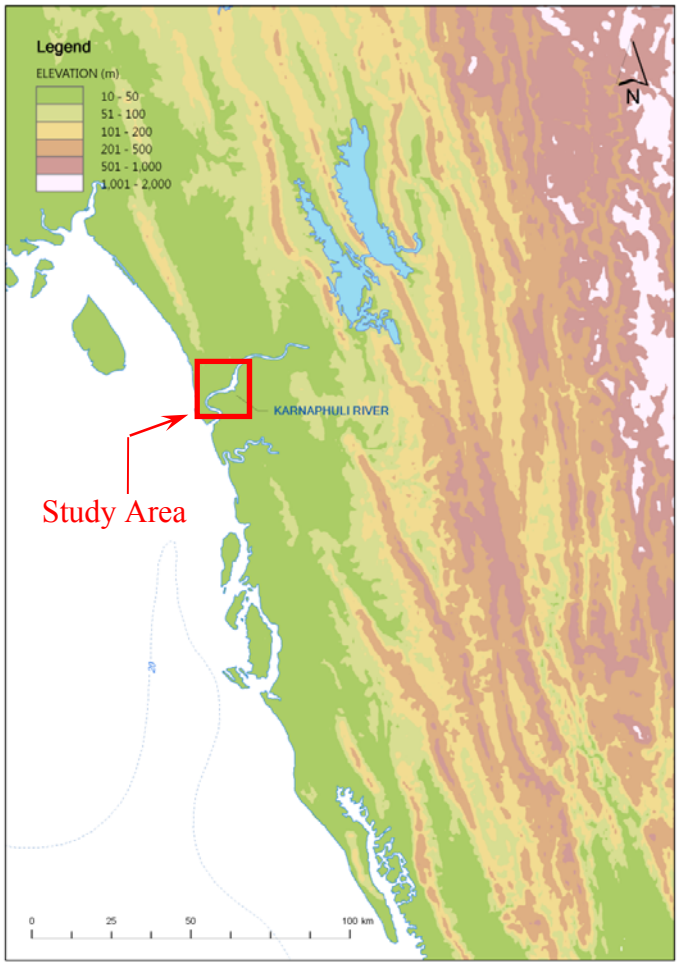


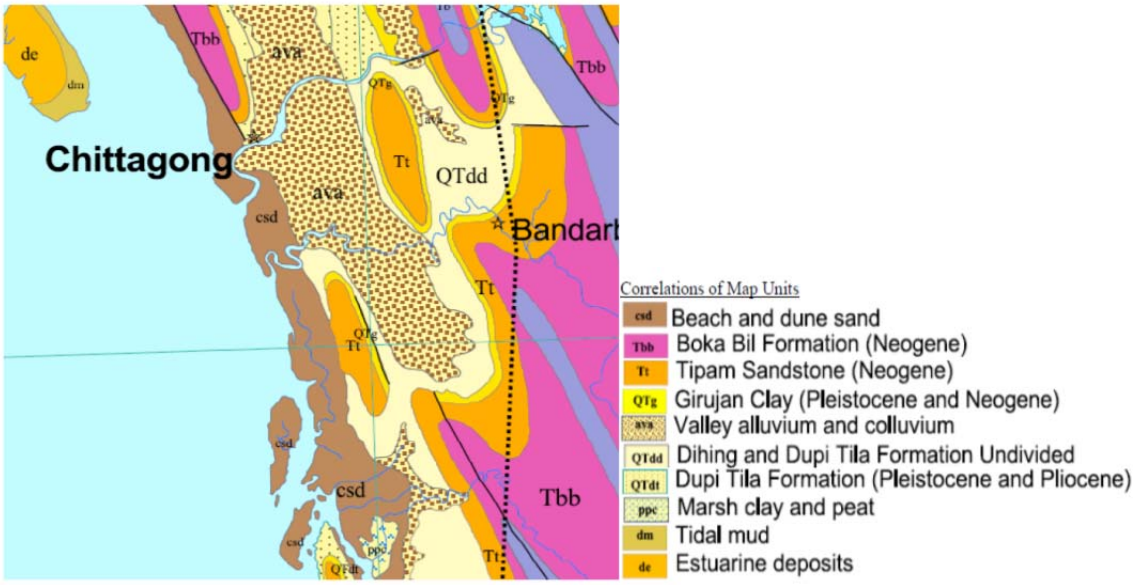
Figure 2.3-1 Topography of Proposed Study Area

Chittagong Division is situated in the eastern hilly part of Bangladesh, which is characterised by a north-south trending folded mountain range. The study area and proposed location of tunnel, which is along the Karnaphuli River, can be

considered as a flat area with altitude within 50 metres, as shown in **Figure 2.3-1**. More specifically, the major regional topography of the area is characterised by flood plain deposits with numerous depressions such as ditch and marshy land. The general elevation of the area stays within 0.1m to 10m. The region is in early geomorphic cycle of erosion and sub aerial weathering. The gentle slopping Karnaphuli River in the western flank gradually merges into the Bay of Bengal.

2.4 Geology

A recent surface geology study of Chittagong area shows that the surface geology of the area consists of "csd" and "ava" types of formation, which stands for beach and dune sand formation and valley alluvium and colluvium (shown in **Figure 2.4-1**).



Source: SURVEY 2000

Figure 2.4-1 Geological Map of Chittagong

Surface geology of the Chittagong City area has two distinct patterns. Quaternary sediments are exposed in the southern part of the study area in between Karnaphuli River to the east and south and Bay of Bengal to the west. Tertiary sediments are mainly exposed in the northern part of the study area. Piedmont and valley fill deposits are found to cover the surface at western and eastern side of the northern half.

For the subsurface geology, three soil layers were observed in the studied site such as silty CLAY, sandy SILT and silty fine SAND. A typical section showing the subsurface condition is illustrated in the **Figure 2.4-2** and **Figure 2.4-3** .

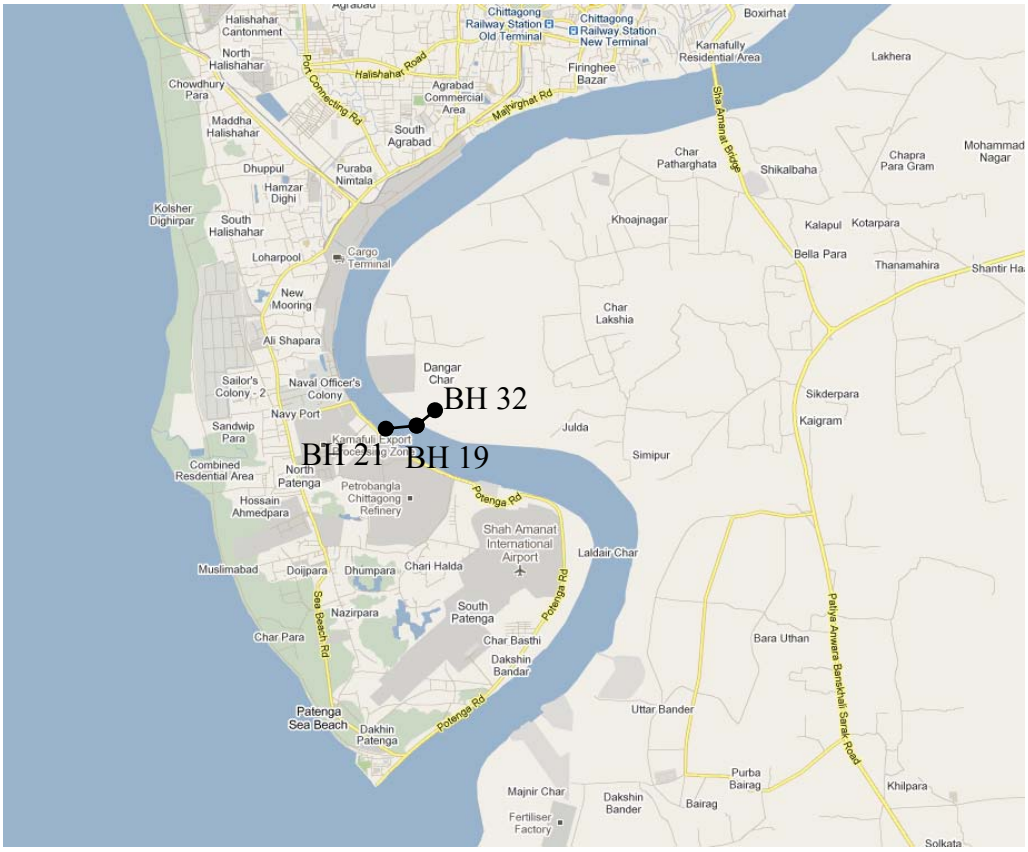
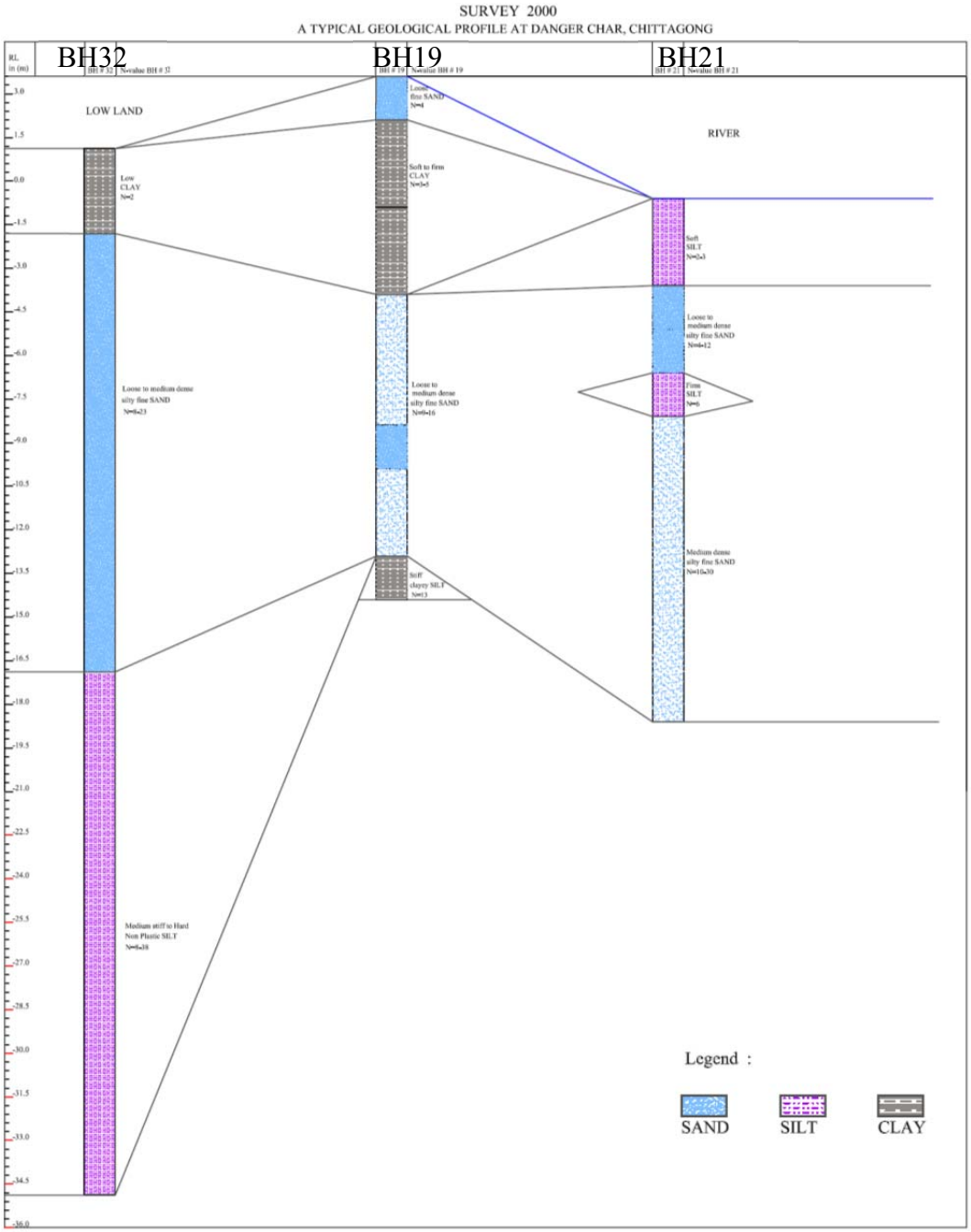


Figure 2.4-2 Location of Boreholes (indicative only)



Source: SURVEY 2000

Figure 2.4-3 Typical Geological Section of Chittagong

2.5 Hydrology

Chittagong City was experiencing a large amount of annual rainfall. It fluctuated periodically in the last 23 years. The maximum is approaching 5000mm/annum while the minimum is about 2000mm/annum in 2010. In addition, on average the monthly rainfall at Chittagong exceeded 200mm for over half of the entire year, starting from May to October, with a maximum even up to just below 800mm in July. As a result of the heavy and long-persistent rainfall, flooding may have a considerable influence on the tunnel portal design.

2.6 Hydrogeology

Groundwater condition is determined by high rainfall and flooding in monsoon period and geological setting of the country. Aquifers belong to thick semi-consolidated to unconsolidated fluvio-deltaic sediments of Miocene to the present. Except the Dupitila Sandstone Formation of the Plio-Pleistocene age, others are too deep to consider for ground water extraction. The groundwater condition of the Chittagong City Corporation area can be divided into two zones (Tertiary zone and coastal zone).

In accordance to records from Chittagong Development Authority[2], the maximum water level of Karnaphuli River is estimated at 4.68m with a return period of 100 years. On the other hand, if tide effect and cyclonic surge are taken into consideration, the estimated maximum water level in the river is expected to reach 6.8m with a return period of 100 years.

2.7 Regional Seismic Effect

According to the Global Seismic Hazard Assessment Programme (GSHAP), Chittagong Division is the most hazardous division in Bangladesh, and the Peak Ground Acceleration (PGA) may be expected to be in the range of 0.24-0.48g.

[2] Chittagong Stormwater Drainage and Flood Control Plan

3. TRAFFIC SURVEY, ANALYSIS AND FORECAST

3.1 Review of Current Transportation Network in Chittagong and Bangladesh

(1) Overall Transportation Condition of Chittagong City

Chittagong is the second largest and the main port city of Bangladesh. Most of the towns and the ports are situated on the right bank of the River Karnaphuli. 1/10 of the total area of Bangladesh with 1/20 population is on the south of Karnaphuli River. The Capital and most of the industries are situated north of Karnaphuli River and the port.

The main transportation modes in Chittagong City are railway, waterways, road and air. The main railway station is in the city centre. The airport lies at south end (in Patenga) of the city. The airport is connected to the city by Double Mooring Road and Patenga Road. Only two districts HQ (Bandarban and Cox's Bazar) lie on the south side of the Karnaphuli River. The transit traffics are mostly between these two areas and Chittagong City (or the Port). Daily passengers cross the Karnaphuli River by: (a) Country boats at different locations of the river; (b) Two bridges: Kalurghat Bridge and Shah Amanat Bridge. The central part of the city is located within the inner city ring by Sheikh Mujib, Tiger Pass Road, CDA Ave, Karnaphuli, Shah Amanat Road. The inner city ring road will be highly functional after completion of ongoing link road (2.5 km) along the bank of the river from Strand Road to a point close to Shah Amanat Bridge.

Traffic can access the city centre by Polo Ground Roads, Railway Station Road, Sadarghat Court Road, Shahid Shorawardi Road, Ander Killa Road and Nabab Sirajdoula Road and Kapasgola Road.

(2) Status quo analysis of traffic flow in Chittagong City

Most of the traffic come from and go to north (Dhaka side) by the following roads of the city: (a) To the centre of the city along the Dhaka Trunk Road; (b) To the port and south of the city along the Port Connecting Road; (c) To the north of the city along Zakir Hossain Road.

The traffic comes from and goes to the North (Hathazari side) along the Hathazari and Baizid Bostami Road. From Kaptai (East), traffic has to cross the Karnaphuli River at Kalurghat Bridge (preferably) and Shah Amanat Bridge to reach Chittagong City through Kaptai Road.

The traffic to Chittagong City from Cox's Bazar District, Bandarban District, and important economic growth centre and Upazila's of the two Districts (i.e. access from the south) has to cross the Karnaphuli River at Shah Amanat Bridge and to a lesser extent from Arakan Road via Kalurghat Bridge.

The tunnel alignment was finally selected by the Government of Bangladesh. One end is close to Naval Academy in Patenga and the other end is close to KAFCO. The starting point was selected on the end point of Costal Road (Patenga to Fouzderhat i.e. at Dhaka-Chittagong Highway). It serves transit traffic as well as city traffic towards Rongadia Industrial Area, Anwara Upazila and Cox's Bazar which is the city of tourism. It is expected that a considerable number of transit

traffic will generate and use the proposed tunnel after the completion of Sonadia Deep Sea Port and Link Road with Myanmar..

3.2 Traffic Survey, Analysis and Forecast

The main objective of traffic survey and analysis is to determine the extent of traffic demand likely to cross the Karnaphuli River through the road tunnel. The traffic would be generated from the south of the river. At present, transit traffic crosses the river through two existing bridges. A part of the transit traffic will use the tunnel along with the traffic to both sides of the city.

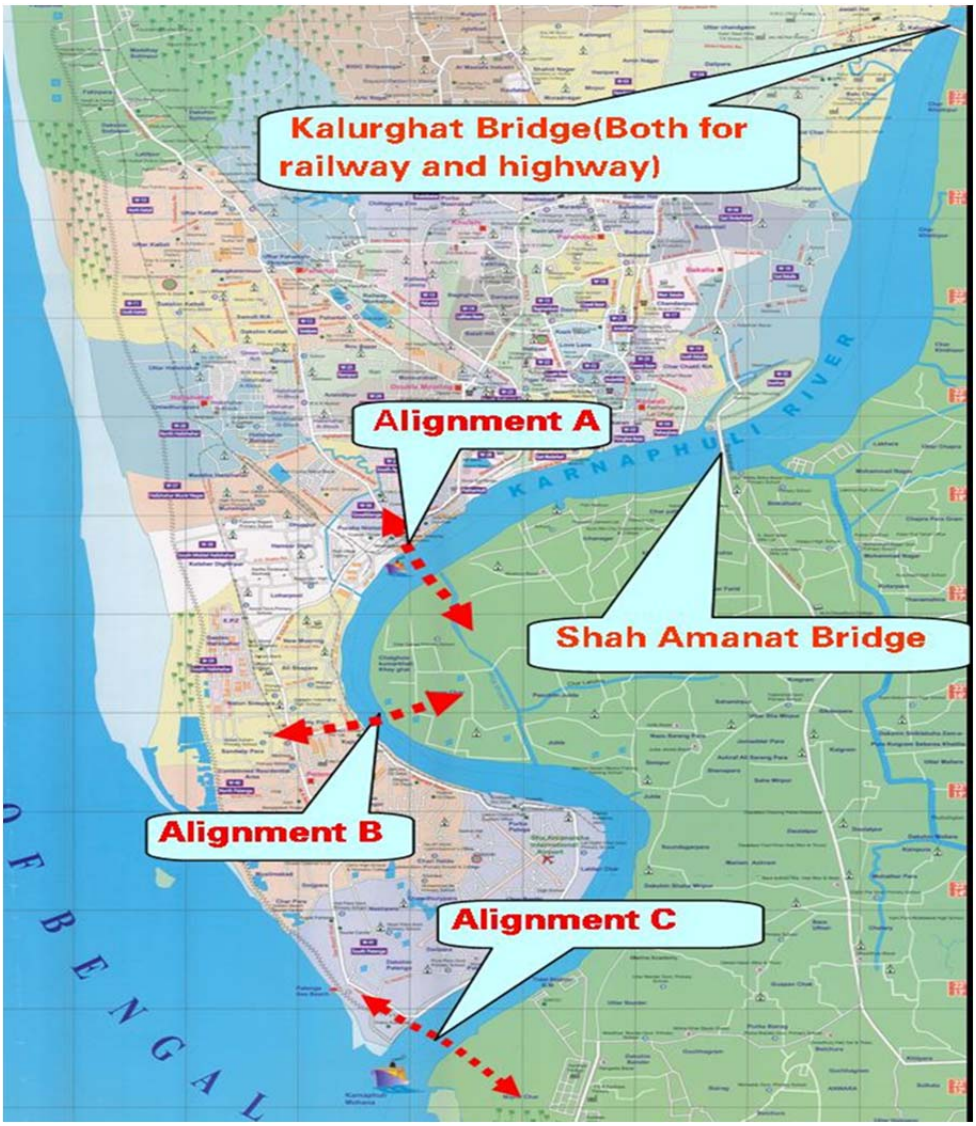


Figure 3.2.1-1 Possible tunnel alignments

Possible alignments considered are illustrated as above.

(1) By using the selected Traffic Assignment model, the traffic volume forecast result for each location are calculated and shown in the table below:

	2017	**2020**	**2025**	**2030**	**2036**	**2040**	**2050**	**2060**	**2067**
Tunnel 'A'	27289	34506	47129	63182	84729	100000	148000	205000	248000
Increase rate		8.8%	7.3%	6.8%	5.7%	4.50%	4.80%	3.90%	3.00%
Tunnel 'B'	16376	20058	27273	36620	48783	60000	85002	120000	145002
Increase rate		7.5%	7.2%	6.9%	5.5%	5.70%	4.20%	4.10%	3.00%
Tunnel 'C'	17374	20719	28305	37946	51273	62000	90000	130000	162000
Increase rate		6.4%	7.3%	6.8%	5.9%	5.20%	4.50%	4.40%	3.50%

Table 3.4.1-1 Traffic Volume Forecast Result (PCU/d)

The increase rate is over 7% due to future development on the southeast side of the river that will generate more traffic to cross the river via the tunnel. More areas will be developed and traffic volume will increase between Year 2020 and Year 2030. The difference in increase rate among tunnels is the location and accessibility of the tunnel for the traffic.

(2) According to the analysis of the traffic survey data and the existing vehicle composition, the composition of the traffic is shown as follows:

Tunnel A:

Year	Heavy Truck Trailer Container	Medium Truck	Small Truck Pickup Small Van	Large Bus	Mini Bus	Microbus	Utility	Car, Jeep/Van	Sum
2017	5054	4579	3840	2169	3272	5087	388	2901	27289
2020	6390	5790	4855	2743	4137	6432	490	3668	34506
2025	8728	7908	6631	3747	5651	8785	669	5010	47129
2030	11701	10602	8890	5023	7575	11777	897	6716	63182
2036	15692	14217	11921	6736	10159	15793	1203	9007	84729
2040	18520	16780	14070	7950	11990	18640	1420	10630	100000
2050	27410	24834	20824	11766	17745	27587	2102	15732	148000
2060	37966	34399	28844	16298	24580	38212	29114	21792	231205
2067	45930	41614	34894	19716	29735	46227	3522	26362	248000

Table 3.4.1-2 Tunnel A Traffic Forecast Result

Tunnel B:

Year	Heavy Truck Trailer Container	Medium Truck	Small Truck Pickup Small Van	Large Bus	Mini Bus	Microbus	Utility	Car, Jeep/Van	Sum
2017	3033	2748	2304	1302	1963	3052	233	1741	16376
2020	3715	3366	2822	1595	2405	3739	285	2132	20058
2025	5051	4576	3837	2168	3270	5084	387	2899	27273

2030	6782	6145	5152	2911	4391	6826	520	3893	36620
2036	9035	8186	6864	3878	5849	9093	693	5186	48783
2040	11112	10068	8442	4770	7294	11184	852	6378	60100
2050	15742	14263	11960	6758	10192	15844	1207	9036	85002
2060	22224	20136	16884	9540	14388	22368	1704	12756	120000
2067	26854	24331	20402	11528	17386	27028	2059	15414	145002

Table 3.4.1-3 Tunnel B Traffic Forecast Result

Tunnel C (Recommended option)

Year	Heavy Truck Trailer Container	Medium Truck	Small Truck Pickup Small Van	Large Bus	Mini Bus	Microbus	Utility	Car, Jeep/Van	Sum
2017	3218	2915	2445	1381	2083	3239	247	1847	17374
2020	3837	3477	2915	1647	2484	3862	294	2202	20719
2025	5242	4750	3983	2250	3394	5276	402	3009	28305
2030	7028	6367	5339	3017	4550	7073	539	4034	37946
2036	9496	8604	7214	4076	6148	9557	728	5450	51273
2040	11482	10404	8723	4929	7434	11557	880	6591	62000
2050	16668	15102	12663	7155	10791	16776	1278	9567	90000
2060	24076	21814	18291	10335	15587	24232	1846	13819	130000
2067	30002	27184	22793	12879	19424	30197	2300	17221	162000

Table 3.4.1-4 Tunnel C Traffic Forecast Result

3.3 The Hierarchy of Tunnel Road and Design Speed

(1) The hierarchy of Tunnel

Alignment C is considered as the best option in providing river-crossing service for transit traffic, establishing a fast channel among the three cities of Dhaka – Chittagong – Cox's Bazar, and satisfying the regional transportation development demand of Bangladesh. Alignment C is recommended from this study.

Alignment C is located at the estuary of the Karnaphuli River, about 2km downstream of the airport. The western connecting point could be Kamal Atatuik Ave, and extend westward to the planned Costal Road of Bengal Bay. The alignment connects with local existing road Banskhali Sarak Road on the east bank and further extends eastward to Cox's Bazar Road. Both Costal Road of Bengal Bay and Cox's Bazar Road are part of the national highway in Bangladesh highway network. According to the urban master planning of Bangladesh and urban traffic plan of Chittagong, the hierarchy of Costal Road of Bengal Bay and the Cox's Bazar Road connecting to the portals of Alignment C are expressway and urban trunk road respectively. Expressway standard is recommended.

(2) Design Speed

This project is designed as a high-grade expressway, functioning concurrently as urban road. Design speed of 80km/h is adopted.

3.4 Analysis of Service Level and Lane Requirement of Tunnel

3.4.1 Lane Requirement of Tunnel

According to analyses and calculations, the number of the lanes for the tunnel is 4 lanes in total (2 lanes each side).

3.4.2 Level of Service of Tunnel

The service level of this project is evaluated by referring to the grade classification of service level for multi-lane highway in HCM (Highway Capacity Manual), and based on the traffic forecast results of this project. Level of service (LOS) is classified in six grades, A, B, C, D, E, and F. Grade A service level stands for the best operating conditions while grade F the poorest.

Year	2017	2020	2025	2030	2036
Maximum service flow rate V_p（pcu/h/ln）	568	678	926	1241	1677
Service level	A	A	B	C	D

Table 3.4.2-1 Calculation Result of Service Level

The maximum service flow rate is calculated using traffic volume and capacity. As shown in the Error! Reference source not found., the whole line of this project can still maintain Grade D service level until Year 2036 in the long-term design.

3.5 Summary

Considering the road network plan, traffic volume forecast, overall transportation system, and long-term development of the project area, expressway service level analysis was demonstrated. Dual-two lanes expressway standard with design speed of v=80km/h is recommended for Alignment C.

4. TUNNEL ALIGNMENT SELECTION

4.1 Study of Possible Alignment Locations

Six tunnel alignments were put forward initially, among which Site 1 and Site 2 were located at the suburb northeast of Chittagong downtown area, Site 3 and OP2 were located at the central downtown area of Chittagong, and Site 4 and Site 5 were located at the suburb southwest of Chittagong downtown area as shown in **Figure 4.1-1**.

Figure 4.1-1 Location Map of Alignment Options

Site 1 is located nearby Kalurghat Railway Bridge northeast of Chittagong and far away from the downtown area (about 7km). The river crossed by this alignment is short, but the road network structures at both ends of it are simple, which are unable to fully exert the service function of the tunnel; meanwhile, as this alignment is too near to the railway bridge, the tunnel construction may impact the railway bridge to some extent.

Site 2 is located at about 3km east of Chittagong downtown area. The river crossed by this alignment is wide, the tunnel scale is large, and the road network structures at both ends of it are simple; therefore it cannot fully exert the service function of the tunnel as well.

Site 3 is located nearby Sha Amanat Bridge, connecting the Chittagong downtown area and the east bank of Karnaphuli. This alignment is good in providing service for downtown traffic, but the connecting roads are relatively low in grade and it is too close to Sha Amanat Bridge, the traffic function of it overlaps with the bridge and the tunnel construction may impact Sha Amanat Bridge to some extent.

OP2 is also located at the Chittagong downtown area. This alignment is good in providing service for downtown traffic, but the connecting roads are relatively low in grade, too.

Site 4 is located at the suburb southwest of Chittagong. The west start point of this alignment may connect to the planned Costal Road, thus can provide certain transit traffic service, but this alignment is too close to the naval base and may impact the base to some extent.

Site 5 is located at the estuary in remote southwest suburb of Chittagong. It is featured by wide open space and good construction conditions, and it can connect to the planned Costal Road, too, thus having strong transit traffic service functions.

Through data collection and survey, OP2, Site 4 and 5 are thought to have good research value and are optimized. Alignments A, B and C are finally identified as the options studied in detail in the feasibility study stage, which are as shown below:

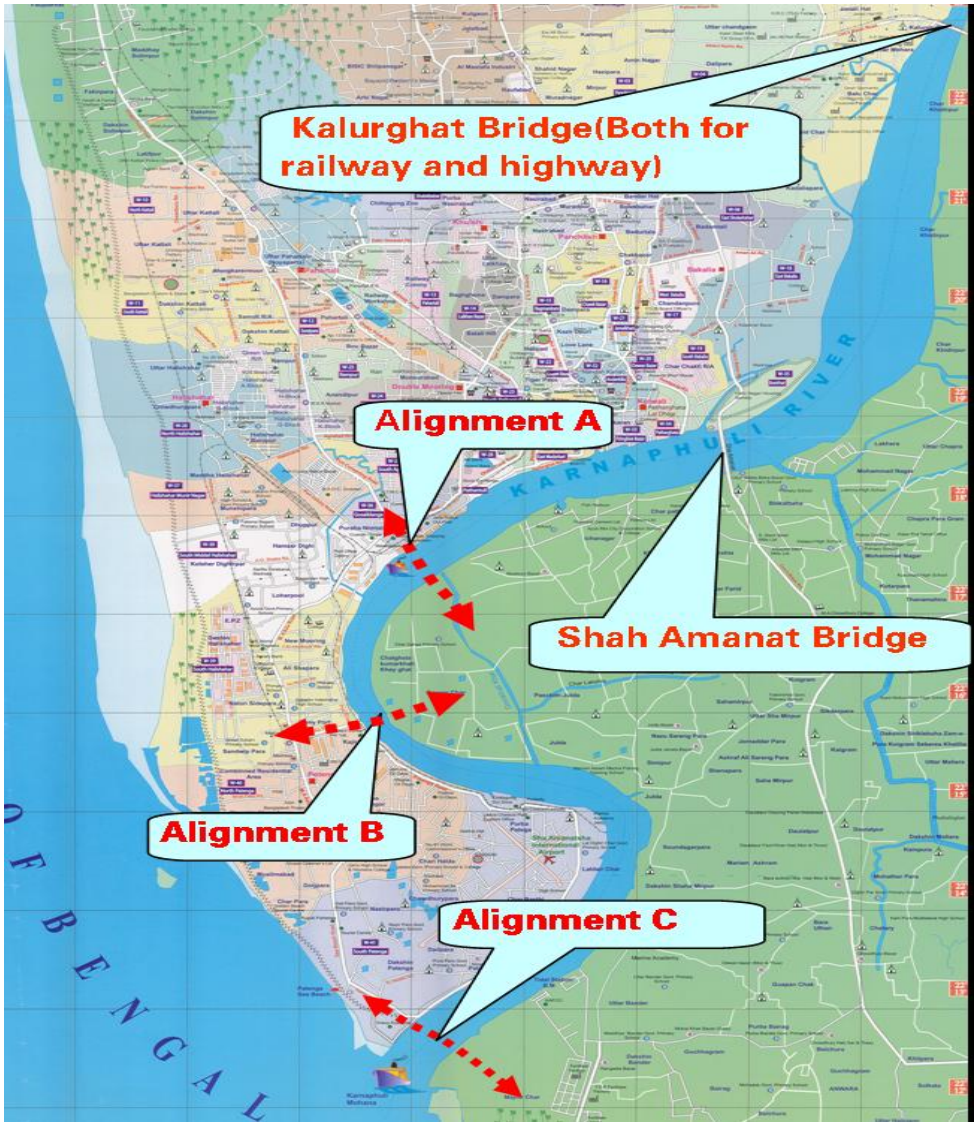


Figure 4.1-2 Layout Plan of Major Alignment Options

Alignment A: The tunnel will connect to Port Connecting Road on the west bank and further to Dhaka Truck Road northward, and connect to Cox's Bazar Road eastward.

Alignment B: The tunnel will connect to the Planned Costal Road of Bengal Bay and further to Dhaka Truck Road northward, and connect to Cox's Bazar Road eastward.

Alignment C: On the west bank, the tunnel will connect to Kamal Atatuik Ave and further to downtown area road network of Chittagong City through Sea Beach Road, M.A Azia V.I.P Road. The tunnel can also extend westward to the planned Costal Road of Bengal Bay and connect with the Dhaka Truck Road. On the east bank, the tunnel will connect to the existing local road, which will be expanded and re-constructed, then connect to the trunk road (Patiya Anwara Banskhali Sarak Road) and further to the CoxSea Beach Road, M.A Azi

The Chittagong City is connected with Dhaka through Dhaka Truck Road in the north direction. In the south direction, it is connected with the proposed Asian

Highway through Cox's Bazar Road, and will reach Myanmar through the Asian Highway.

4.2 Detailed Comparison of Tunnel Alignments

AASHTO codes and standards are referred in comparing the alignment options of this project.

Based on the initial site visits and the collected data, the alignment options A, B and C as illustrated below are thought to have higher study value. All the three alignments have their unique advantages; detailed study, analysis, and comparison on the three alignments are presented as follows:

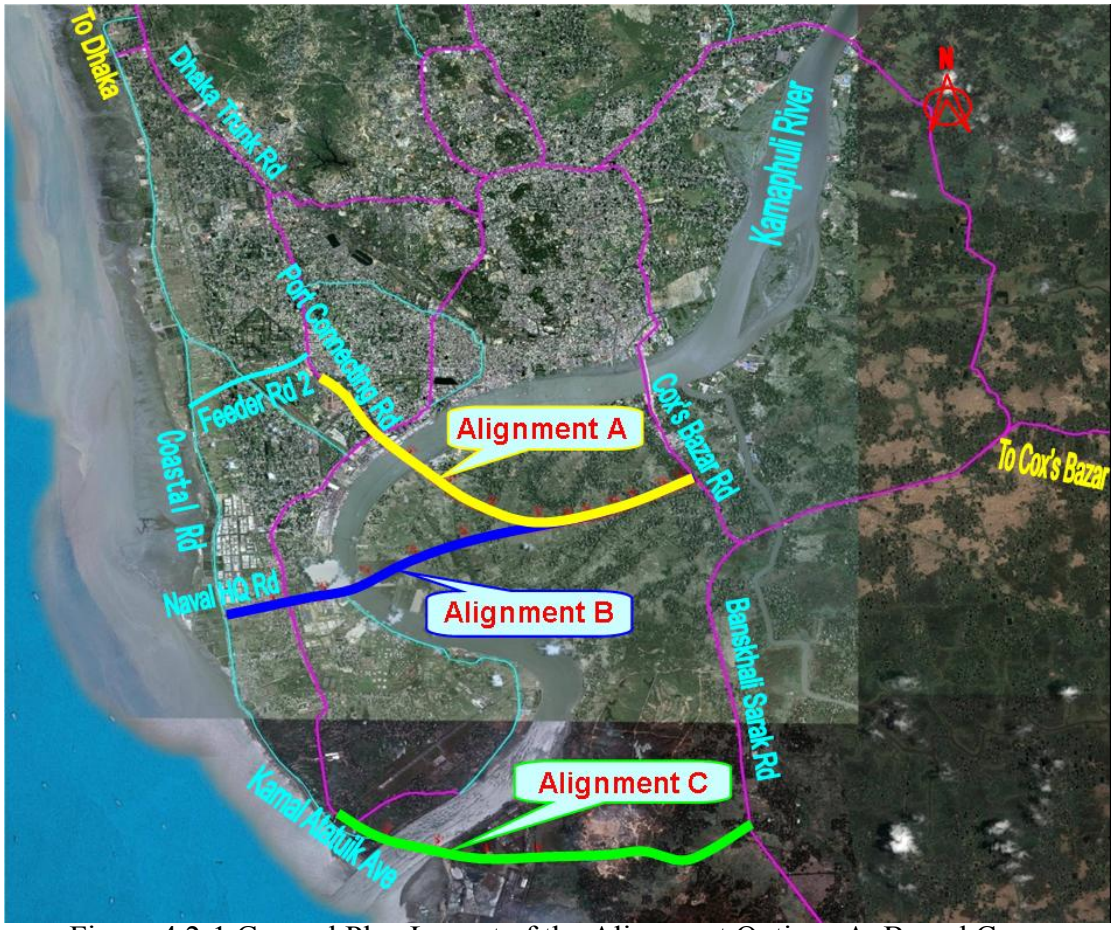


Figure 4.2-1 General Plan Layout of the Alignment Options A, B, and C

4.2.1 Detailed Study of Alignment A

4.2.1.1 Determination of Plan Location

Alignment A is located at the west side of the downtown area, about 7.0～7.5km downstream of the Shah Amanat Bridge. The west bank connecting point is Port Connecting Road. The alignment is proposed along Port Connecting Road from west to east. The tunnel portal is located at about 700m west of the tributary 1 of the Karnaphuli River. The tunnel goes eastward under the tributary 1, Mooring Road, Port Internal Road, Port Dock in succession, and then passes under

Karnaphuli River to the east bank of Chittagong and reaches the ground. After that, Alignment A extends eastward to Cox's Bazar Road. The total length of Alignment A is 9310m, including 4010m for the principal part (3620m for the tunnel), 850m for the west bank approach, and 4450m for the east bank approach. The minimum radius of Alignment A is R=1000m, and the width of the river crossed is about 680m. The segment crossing the river is straight and one working shaft is set up at each bank of Karnaphuli River.

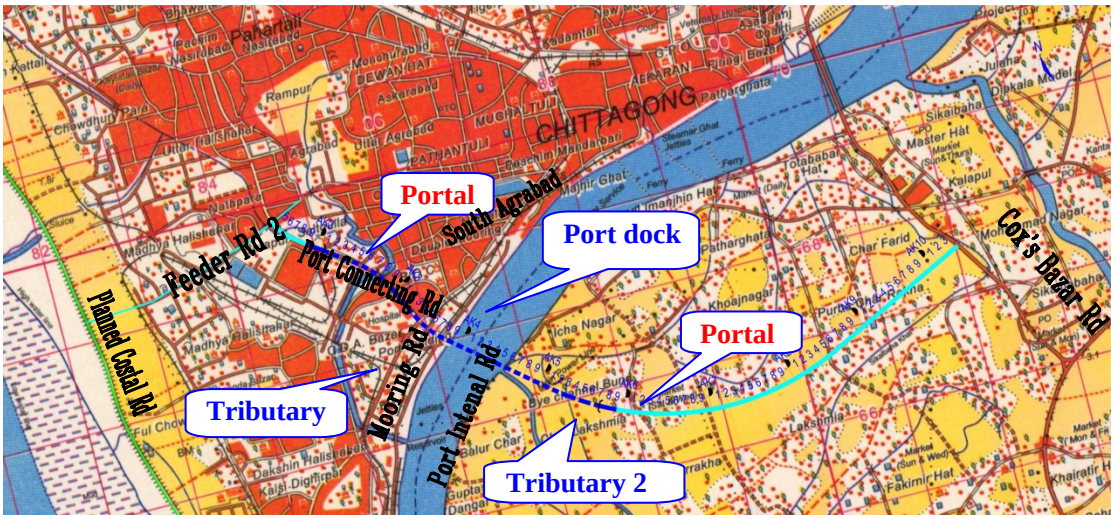


Figure 4.2.1.1-1 Plan Layout of Alignment A

4.2.1.2 Determination of the Longitudinal Section

The area where Alignment A locates suffered from serious riverbed scour. Meanwhile, the elevation of ground on the east bank is relatively low. Therefore, the flood control requirements shall be taken into account in the design of the longitudinal section of the tunnel. The construction of cofferdam is adopted to meet the requirement of 100-year return period flood control. Longitudinal section is proposed as follows.

The Longitudinal Section of Alignment A by Shield-driven Method

This alignment adopts U-type longitudinal slope. The tunnel departs from the ground on the west bank with a slope of 0.576% (95m), and then a downslope of -4% (835m) to enter the shield-driven tunnel, a gentle slope of -2.3% (220m) and a down slope of -4%(900m) to reach the deep trench in the river, and then an upslope of 4% (900m), 2.3% (220m) and an upslope of 4% (900m) gradually rising to exit the tunnel, and finally a slope of -0.728% (130m) to the ground on the east bank. The thickness of the covered-soils of the shield tunnel under the river shall not be less than 1 time of the tunnel diameter. One working shaft shall be provided on each bank of the river. The thickness of overlaid soils of the working shaft shall not be less than 0.5 times of the tunnel diameter. Cofferdam is adopted to retain the area surrounding the east portal in order to meet the requirements of 100-year return period flood control.

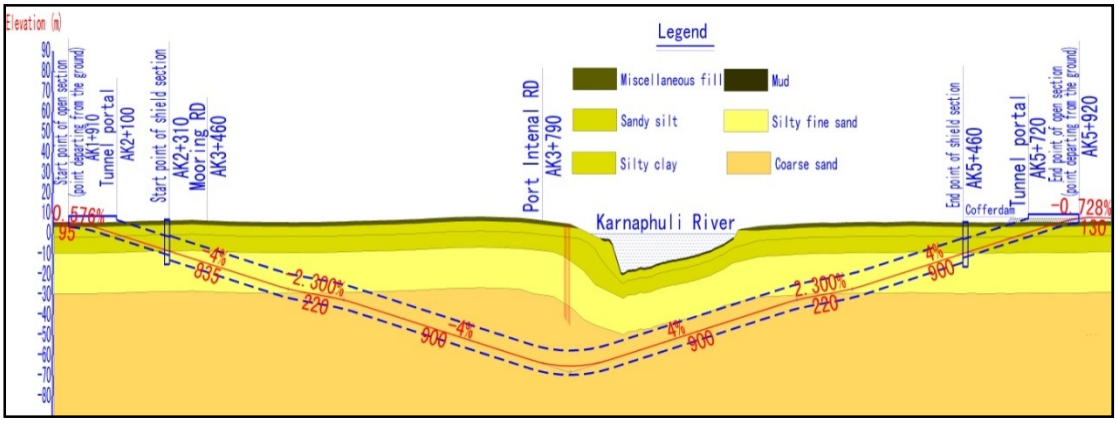


Figure 4.2.1.2-1 Drawing of the Longitudinal Section for Alignment A by Shield-driven Method

Name of Section	Open-cut section	Cut & cover section	Working shaft on the west bank	Shield-driven section	Working shaft on the east bank	Cut & cover section	Open-cut section
Length of the section (m)	190	190	20	3150	20	240	200
Sum of sections (m)	190	210		3150	260		200
Total length of the tunnel (m)		3620					
Total length of the tunnel principal part (m)	4010						

Table 4.2.1.2-1 Length of Alignment A by Shield-driven Method

4.2.2 Detailed Study of Alignment B

4.2.2.1 Determination of Plan Location

Alignment B is located in the suburban area on the west of downtown Chittagong. It is about 6.0～7.0km upstream from the airport. The western portal is connected to the planned Costal Road. The alignment is arranged along Naval HQ Road from west to east. The portal is located at about 50m from the west side of the M.A Azia V.I.P Road. The tunnel goes eastward under M.A Azia V.I.P Road,

Potenga Road in succession, reaches the riverside near the southeast corner of the Bangladesh Navy Base, and then passes under Karnaphuli River to the east bank of Chittagong and reaches the ground. After that the alignment extends eastward to Cox's Bazar Road. The total length of Alignment B is 9745m, including 3020m for the principal part (2600m for the tunnel), 1050m for the west bank approach, and 5675m for the east bank approach. The minimum radius of Alignment B is R=1000m, the width of the river crossed is about 460m, the section crossing the river is straight and both banks of Karnaphuli River are provided with a working shaft.

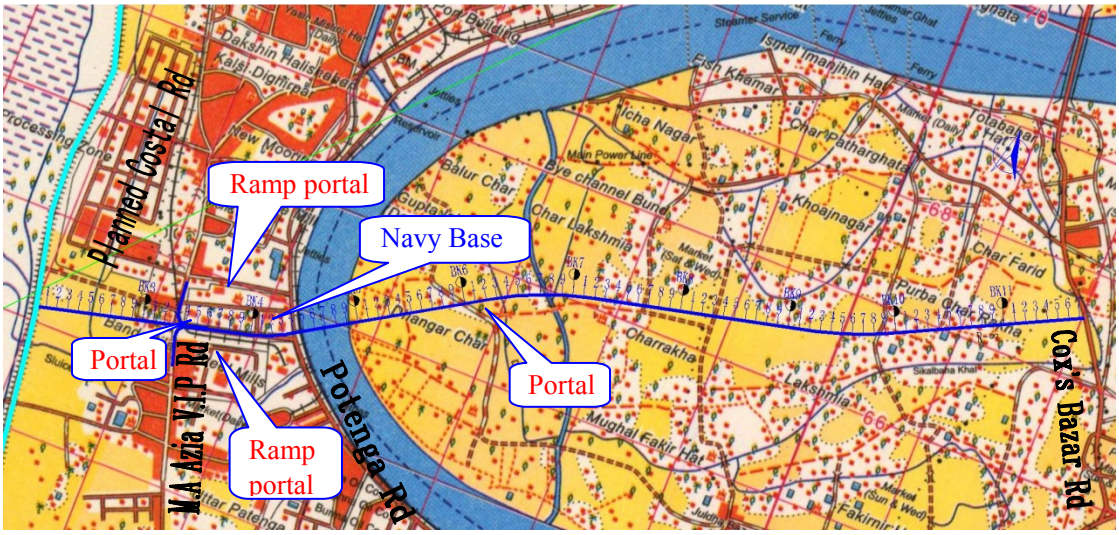


Figure 4.2.2.1-1 Plan Layout of Alignment B

4.2.2.2 Determination of Longitudinal Section

Although watercourse crossed by Alignment B is relatively narrow, the riverbed scour is very serious. Longitudinal section is determined as follows:

1) Longitudinal Section of Alignment B by Shield-driven Method

This option adopts U-shape longitudinal slope. The alignment starts with a slope of 0.656%(160m) departing from the ground on the west bank, a downslope of -4%(320m) entering the tunnel, a gentle slope of -1.5%(270m) and a downslope of -4%(900m) descending to and passing the deep trench in the river, an upslope of 2.5%(500m) and an upslope of 4%(1000m) gradually rising to exit the tunnel, a slope of -0.5%(180m) to the ground on the east bank. Overlaid soil of both tunnel in the river and working shaft on the bank should meet the minimum thickness requirements. The cofferdam is also adopted near the tunnel portal on the east bank in order to meet the requirements for flood control.

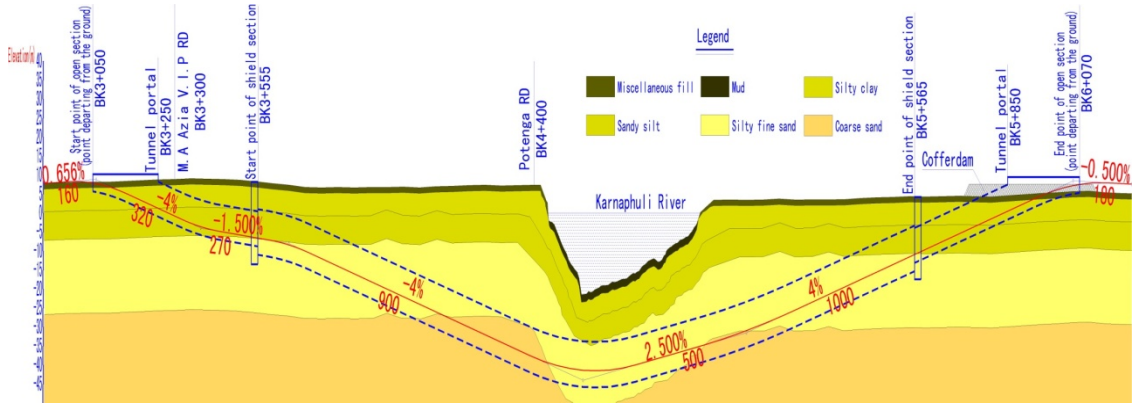


Figure 4.2.2.2-1 Drawing of Longitudinal Section of Alignment B by Shield-driven Method

Name of Section	Open-cut Section	Cut & cover Section	Working shaft on the west bank	Shield driven Section	Working shaft on the east bank	Cut & cover Section	Open-cut Section
Length of the Section (m)	200	285	20	2010	20	265	220
Sum of Sections (m)	200	305		2010	285		220
Total length of the tunnel (m)		2600					
Total length of the principal part (m)	3020						

Table 4.2.2.2-1 Length of Alignment B by Shield-driven Method

4.2.3 Detailed Study of Alignment C

4.2.3.1 Determination of Plan Location

Alignment C is located at the estuary downstream of Karnaphuli River, about 2km downstream of the airport. The western connecting point is Kamal Atatuik Ave. In the future, it can extend westward to the Planned Costal Road and reconstruction can be made to the grade crossing of See Beach Road-Kamal Atatuik Ave to optimise the functions of this project. The alignment is located along Kamal Atatuik Ave from west to east. The tunnel portal is about 50m from the west of N Awalia Road. The tunnel goes eastward under N Awalia Road and Potenga Road in succession to the northeast corner of Naval College, and then goes under the Karnaphuli River to the east bank of Karnaphuli River. The east portal is located at the floodplain outside the embankment of east bank and cofferdam is provided to meet the flood control requirements. Viaduct is formed to overpass the KAFCO conveyor belt and the embankment so as to reduce the impact on them by this alignment. Under the conditions that the clearance of KAFCO conveyor belt and

the embankment is enough for vehicles, the main alignment is smoothly connected with the existing local road on the east bank at the estuary. Although the existing local road on the east bank is planned to be 120 feet wide, its current width and indexes are relatively low, thus requiring further improvement and reconstruction. Alignment C connects with Banskhali Sarak Road in the eastward direction along existing local road and further extends eastward to Cox's Bazar Road. The total length of Alignment C is 9092m, including 3400m for the principal part (3050m for the tunnel), 740m for the west bank approach, and 4952m for the east bank approach (including the reconstruction of the existing local road). The minimum radius of Alignment C is 718.5m (minimum radius of tunnel is 1500m) and the river width is about 1075m. The sections crossing the river is straight and one connection shaft is provided on each bank of the Karnaphuli River.

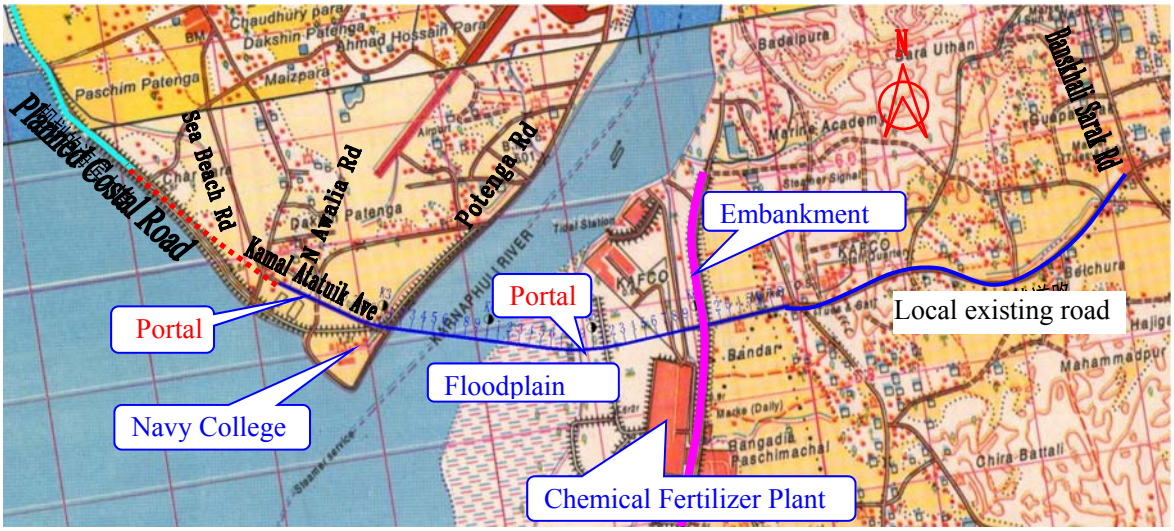


Figure 4.2.3.1-1 Plan Layout of Alignment C

4.2.3.2 Determination of Longitudinal Section

Alignment C is located at the estuary, and the elevation of the floodplain on the east bank is low, if the tunnel locates its portal on the floodplain, the perimeter of the portal should be retained by a cofferdam to ensure that the crest elevation of the tunnel portal satisfies the 100-year return period flood control requirements. The crest elevation of the east tunnel portal after cofferdam retaining should be ensured to be no less than 7.3m (MSL elevation system). In addition, the terrain of the riverbed in this section is relatively gentle, so the riverbed scour is not severe and will not cause great impact on the longitudinal section of the shield tunnel.

Longitudinal Section for Alignment C by Shield-driven Method

Alignment C adopts U-type longitudinal slope. The western connecting point starts with a slope of -0.384%(740m) departing from the ground, and then a downslope of -4%(500m) entering the tunnel, and a gentle slope of -2.4%(230m)and a downslope of -4%(570m) descending to the deep trench in the river. The tunnel runs parallel to the riverbed with a gentle slope of 0.5%(810m), and then gradually rises with an upslope of 4%(880m), a gentle slope of 2.3%(230m), and an upslope of 4%(530m) to the east portal. The alignment passes over the embankment through viaduct and lands on the east side of the embankment and connects to the existing local road on the east bank of

Karnaphuli River, which needs optimization and reconstruction. The overlaid soils of the shield tunnel under the river and working shaft shall meet the minimum requirement of thickness, and the perimeter of the east portal shall be retained by cofferdam to meet the requirement of flood control.

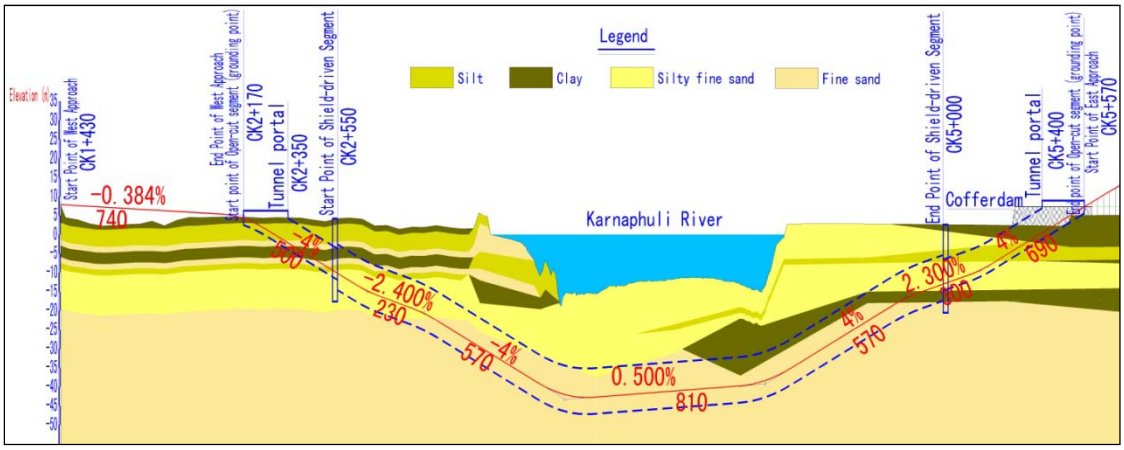


Figure 4.2.3.2-1 Drawing of Longitudinal Section of Alignment C by Shield-driven Method

Name of Section	Open-cut Section	Cut & cover Section	Working shaft on the west bank	Shield driven Section	Working shaft on the east bank	Cut & cover Section	Open-cut Section
Length of the section (m)	180	180	20	2450	20	380	170
Sum of sections (m)	180	200		2450	400		170
Total length of the tunnel (m)		3050					
Total length of the principal part (m)	3400						

Table 4.2.3.2-1 Length of Alignment C by Shield-driven Method

4.2.4 Comprehensive Comparison among Alignment Options

The followings illustrate a comprehensive qualitative comparison on the three alignments from the aspects of service function, traffic function, planning, land acquisition and resettlement, as well as impact on port dock and navy base.

1. Service Function

① Service function for downtown traffic

Alignment A locates at the downtown area of Chittagong. Alignment A is strong in serving downtown traffic and helpful in promoting urban development of Chittagong.

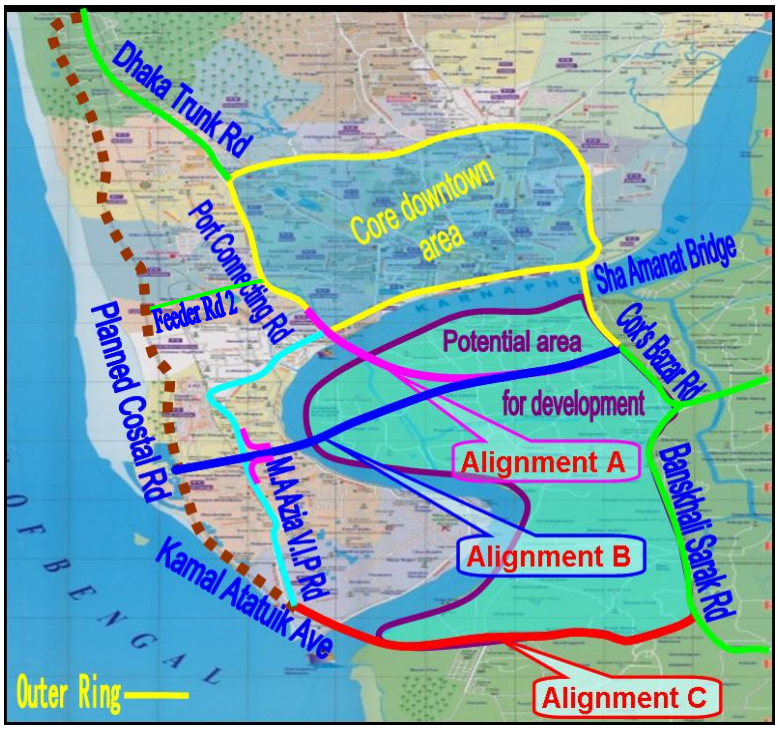


Figure 4.2.4-1 Sketch of Urban Traffic Service Function

Alignment C is located at the estuary in remote suburb of Chittagong, the downtown traffic has to make a large detour if using this alignment; therefore Alignment C is very weak in serving downtown traffic. However, it forms a larger traffic ring with Sha Amanat Bridge and relevant road network. It can serve the urban area in the long term.

Alignment B is located between Alignment A and C, it can reach the urban area by using an underground ramp to connect with M.A Azia V.I.P Rd, the distance to the downtown is shorter than Alignment C; therefore, the function of alignment B in serving downtown traffic is also between Alignment A and C.

② Service function for transit traffic

Alignment C is strong in serving transit traffic. It can relieve the traffic pressure of existing bridges, improve the national highway network and strengthen traffic connection between Dhaka-Chittagong- Cox and the planned Deep Sea Port in south Bangladesh. The construction of this alignment will also play a positive role in propelling Bangladesh towards internationalization.

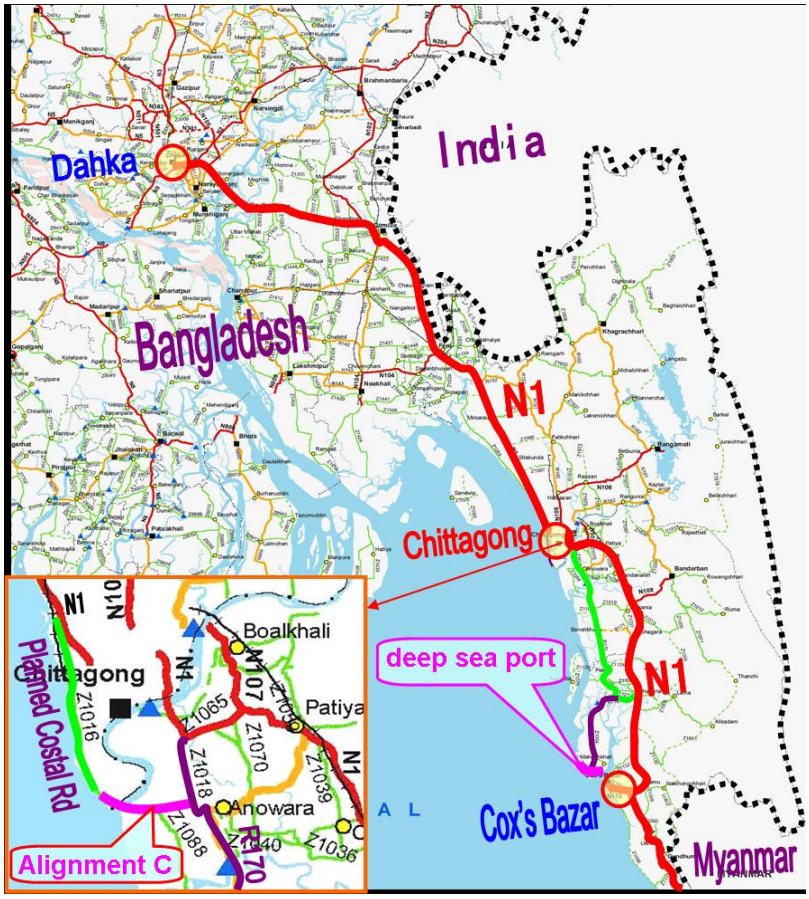


Figure 4.2.4-2 Sketch of Transit Traffic Service Function

Alignment B is also strong in serving transit traffic. However, Alignment B is nearer to the urban area than Alignment C, the downtown traffic will interfere with the transit traffic.

Alignment A is mainly aimed to serve the downtown traffic. The transit traffic will interfere with the downtown traffic; therefore, Alignment A is weak in serving transit traffic.

2. Traffic Function

Based on the traffic volume survey data, the long-term annual traffic of Alignment A is the largest among the three options. The vehicle types on Alignment A will be complex, not only including cars and large transit trucks, but also a large number of non-motor vehicles. Interference will occur between the cars and the trucks which want to drive fast and the slow non-motor vehicles, lowering the tunnel utilization rate, making the tunnel unable to fully play its role, and easy to cause traffic jam. In short term Alignment A can provide river-crossing service for downtown traffic well and share the river-crossing pressure of the downtown area with Sha Amanat Bridge. In long term, as Alignment A is close to Sha Amanat Bridge, with the continuous increase of vehicles in urban area, the tunnel along Alignment A will overlap with Sha Amanat Bridge in terms of meeting the river crossing traffic demands of the downtown area. Certain potential traffic hazards may exist.

The traffic volume of Alignment B is also large. The main vehicle type of Alignment B in short term will be large trucks. In long term traffic of diversified

vehicle types will also be formed. Interference between the downtown cars and the large transit trucks may also occur.

Alignment C is located at remote suburb and the traffic vehicle types are mainly the large transit trucks. The annual traffic volume of Alignment C in the long term will become large. Moreover, Alignment C can also attract part of the river crossing traffic of the downtown area spreading to the suburb, reducing interference between river crossing traffic and internal traffic of downtown area, relieving part of the traffic pressure of downtown area, and giving full way to the fast, convenient and effective traffic functions of this channel.

In addition, the Naval HQ Road at the start point of Alignment B is short and it can only connect to the existing road (M.A Azia V.I.P Rd) by setting an underground ramp, which weakens traffic function of Alignment B to some extent.

In summary, the traffic function of Alignment A and C is relatively strong and that of Alignment B is a little bit weak.

3. Construction scale

Comparison on construction scale focuses on the length and construction cost of each alignment. If only tunnel length is considered, Alignment C $<$ Alignment A $<$ Alignment B; but if the construction cost is also taken into account, Alignment C $<$ Alignment B $<$ Alignment A. However, in general, the project scale of the three alignments is close with little difference.

4. Land acquisition and resettlement

From land acquisition and resettlement point of view, Alignment A is similar to Alignment C, while Alignment B is larger.

5. Building protection

The portal of Alignment A connects Port Connecting Road, the buildings around are dense whilst some important buildings like hospitals, mosques, etc. require necessary protection measures.

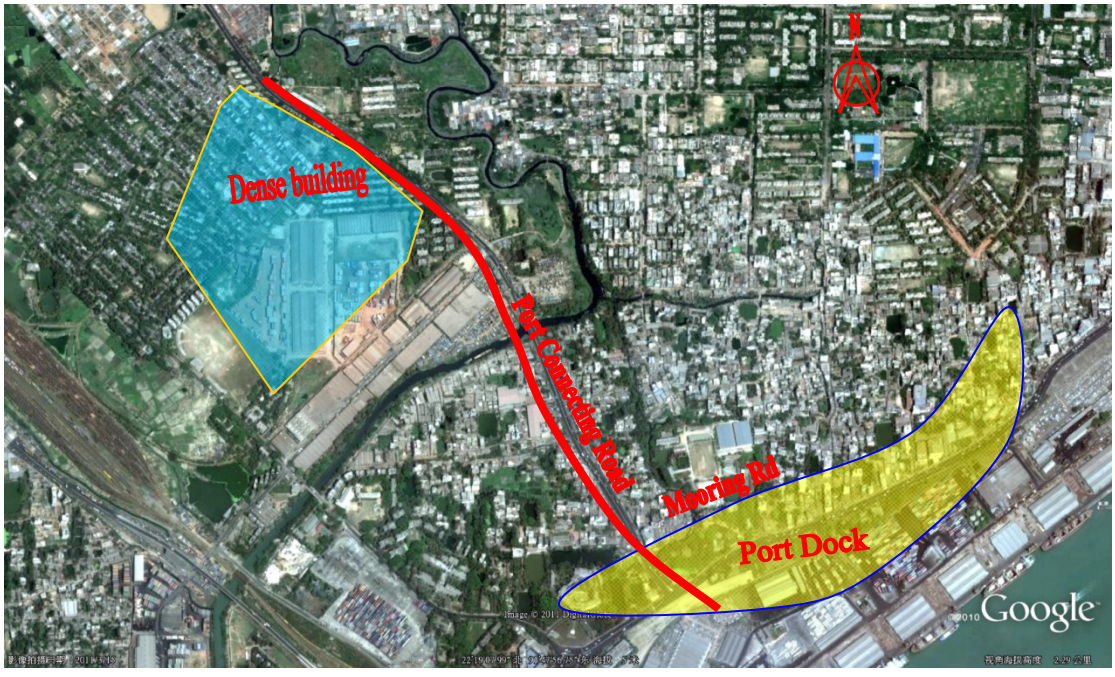


Figure 4.2.4-3 Restraining Structures Distribution along Connecting Roads of Alignment A

The portal of Alignment B not only crosses areas with dense buildings but also the Navy Base, therefore requiring relevant protection measures for important buildings too.

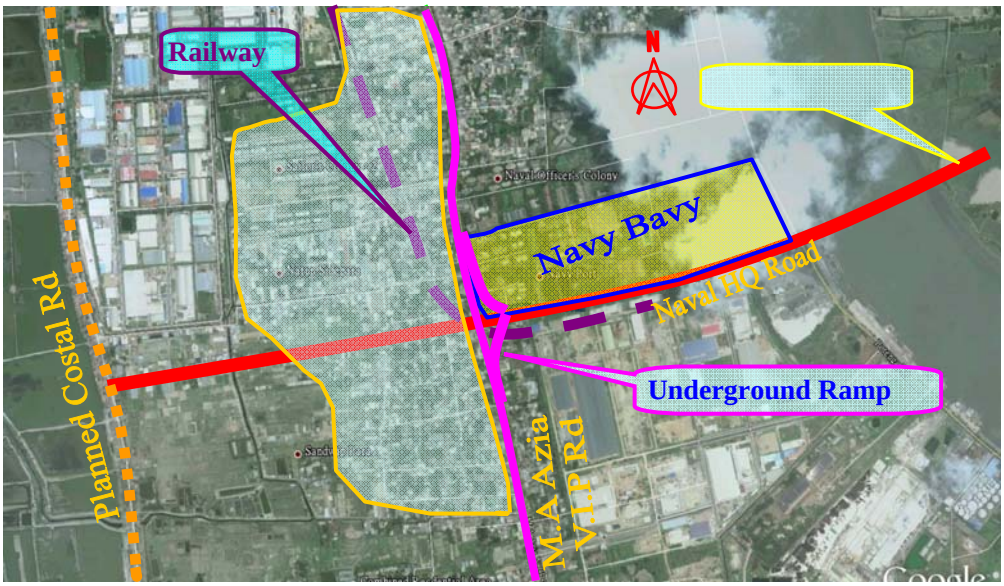


Figure 4.2.4-4 Restraining Structures Distribution along Connecting Roads of Alignment B

The areas along Alignment C are open with few constructions; although it crosses the edge of the Navy College, it produces little effect on it only.

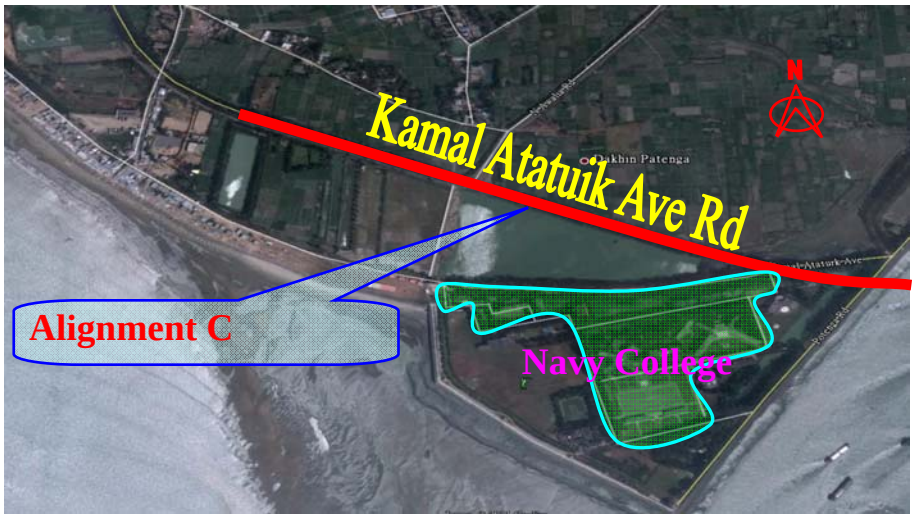


Figure 4.2.4-5 Restraining Structures Distribution along Connecting Roads of Alignment C

6. Impact on port dock

Alignment A on the west bank of Karnaphuli River needs to cross the port dock and will produce relatively large effect on it. Alignments B and C don't pass the port dock.

7. Impact on the Navy base

Alignment B passes by the Bangladesh Navy area, producing relatively large effect on it, liaisons may be difficult in later stage. Alignments A and C are far from the Bangladesh Navy area.

Conclusion

Based on the comprehensive analysis and the consideration of various aspects, the scorings for Alignment A, B, and C are as follows:

Aspect	Full Scores	Alignment A	Alignment B	Alignment C
Service function for downtown traffic	18	18	11	10
Service function for transit traffic	18	10	15	18
Traffic function	15	12	9	13
Land acquisition and resettlement	10	8	4	7
Construction scale	18	14	15	17
Buildings Protection	5	3	2	5
Impact on port dock	8	4	8	8
Impact on Bangladesh Navy area	8	8	4	8
Total Scores	100	77	68	86
Recommendation		②	③	①

Note: The scoring aspects and standards in the table refer to similar underwater tunnel projects in China, such as Xiamen Xiangan tunnel, Shantou suaiwan underwater tunnel, etc.

Table 4.2.4-1 Comprehensive Scoring of Alignment Options for Road Tunnel under the Karnaphuli River

Alignment C is recommended among the three candidate Alignments A, B, and C. On February 22, 2012, BBA made comments to the alignment recommendations in the interim report and agreed to take Alignment C as the recommended alignment.

5. DETAILED INVESTIGATION AND SURVEY

5.1 General

The tunnel alignment selection analysis shows Alignment C located at Patenga is proposed to be the best option.

5.2 Topographic Survey

The Alignment C is adjacent to Bangladesh navy academy at western bank of River Karnaphuli and Anowara at eastern bank, the area identified on both sides of the center-line of the tunnel alignment and approaches up to a length as agreed upon.

The scope of survey is as follows:

i) Topographic survey of land alignment on both bank at 400 m wide strip: 200 m along both side of the center-line of the alignment, and

ii) Cross sections along the land alignment at 20m interval

Detailed topographic survey results can be found from a separate report in the Main Report.

5.3 Hydrographic Survey and Investigation

Bathymetric Survey covered the river cross sections at selected interval of 25 m on the Karnaphuli riverbed covering 200 m on both side of the centerline along the Alignment C. In addition, survey also covered two cross sections at 500 m upstream and 500 m downstream for the centerline of the selected Alignment C.

5.3.1 Scope of Survey

i) Topographic survey underwater of the Karnaphuli River 400 m wide strip: 200 m along both side of the centerline of the proposed alignment.

ii) One River section at 500 m upstream from the centre line of the proposed alignment

iii) One River section at 500 m downstream from the centre line of the proposed alignment

5.3.2 Bathymetric Map

An underwater topographic map of the Karnaphuli River along the Alignment C over a scale of 1:2,000 was prepared covering survey range of 200 m to both sides of the alignment and two additional cross sections at 500 m up and downstream from the centerline of the alignment. The underwater topographic/bathometric cross sections can be found from the Main Report.

5.4 Geological and Geotechnical Investigation

5.4.1 Objectives and Scopes

The objective of the investigation is to find out the engineering geological conditions, hydro-geological conditions and geological structures so as to determine the geotechnical condition surrounding the tunnel. Quantitative assessment on engineering geological characteristics of surrounding rocks/soils, rock/soil stability surrounding the portals and tunnel body, and hydro-geological conditions shall be performed to provide adequate geological basis for tunnel design.

5.4.2 Geological Investigation

5.4.2.1 Geology of Chittagong Area

Geologically the area falls within the Bengal Foredeep of Bengal Basin where Neogene sediments with alternation of shale and sandstone are well developed. The region occupies a vast area between Hinge line and Arakan Yoma Folded system that plays a vital role in the Tectonic activities in Bengal Basin. The regional topography of the area is characterized by flood plain deposits with numerous depressions like ditch, Marshy land etc. The general elevation of the investigated area ranges from -8.8 to 4.395 m. The basement rock is probably encountered between 12 and 15 km depth in Foredeep area. The investigated area lies on the folded flank of the Foredeep which occupy a large number of sub-meridian structures of Chittagong and Chittagong Hill Tracts. The gentle slopping Karnaphuli River in the western flank gradually merges into the Bay of Bengal. The Karnaphuli is the main river in the area which enters into Bangladesh about 95km northeast of Chittagong. Detrital materials derived from highlands of India and Myanmar and deposited on gentle slopes to the South and West.

The Surface geology of the area has a wide variation in geologic units. The sequence and distribution of the geologic units are dominantly controlled by the geomorphic position; the tectonic setup also plays a vital role in distribution and setup. Surface geology of the Chittagong City area has two distinct patterns. Quaternary sediments exposed in the southern part of the study area in between Karnaphuli River to the east and south and Bay of Bengal to the west. Tertiary sediments mainly exposed in the northern part of the study area. Piedmont and valley fill deposits cover the surface at western and eastern side of the northern half. Idea about the subsurface geology is mainly based on the surface geology exposed in the area. The Recent to Pleistocene sediments has been deposited on the eroded surface of late Tertiary rocks. The rock exposures are found along the streams and hill slopes of the city area.

The large hilly area located immediately east of the river mouth is probably a tenant of the Tipam Sandstone Formation of Mio-Pliocene age. Coastal plain contains Quaternary sediments and also exposed Tertiary deposits in the east. The older rock units crop out on the landward side in the east, whereas Quaternary and Recent sediments are deposited at the surface near the coast (**Table 5.4.2.1-1 Error! Reference source not found.**). These sediments are generally grey to yellowish grey, loosely compacted medium to fine grained sand and grey clay or

clayey silt. In some areas the sediments contain humus. Calcareous concretions are common in the clay and silt deposits. However, the sedimentation was influenced by eustatic sea-level rise, tectonic processes and a large and variable sediment supply (Goodbred et al., 2003).

Age	Group	Formation	Lithological Description	Thickness (m)
Recent		Alluvium	Clay, silt and sand, dark colored	-
		Unconformity		
Pliocene		Dihing	Sandstone, ill sorted, pebbly and mottled clay	-
		Unconformity		
Mio-Pliocene		Dupi Tila	Sandstone, yellowish brown, medium grain, massive with subordinate clay	198
		Unconformity		
Miocene		Girujan clay	Shale and silty shale with calcareous bands.	168
		Upper Tipam Sandstone	Sandstone brown, medium grained cross-bedded thick bedded to massive with subordinate silt and clay.	223
	Tipam	Middle Tipam Sandstone	Shale and clay, grey, bluish grey with hard calcareous bands.	92
Miocene		Lower Tipam Sandstone	Sandstone, brown, medium grained, cross bedded with subordinate sand and silt.	405
	Surma	Boka Bil	Sandstone and siltstone with alternation of san, silt and shale. Sandy shale and siltstone with subordinate massive sandstone	495
		Upper Bhuban	Sandstone grey, fine grained moderately consolidated with sandy shale and siltstone.	455
		Middle Bhuban	Sandy shale and siltstone, grey, laminated with subordinate and bluish grey, soft, concretionary hale.	-
		Base not seen		

Table 5.4.2.1-2 Geologic Succession of Chittagong Area (GSB, 1978)

The studied area is covered with mostly of Holocene coastal sediments on the right bank of the river Karnaphuli and to some extend nearby Tertiary hills on the left bank. The drainage pattern, their distribution, landform features and their position in tidal flat areas makes the area as a complex geomorphic region. A geomorphological and the geological maps have been prepared based on the

satellite imageries Landsat (2011), together with few other studies on the geomorphology of Chittagong district (**Figure 5.4.2.1-1** and **Figure 5.4.2.1-2**). On the basis of present landforms, its genesis, evolution and morpho-dynamics the area is mapped into three broad geological map units. Erosional landform, the hilly part of the city is characterized by different types of erosional processes therefore landform have distinctive erosional features whereas, tidal deposits have developed in the area by tidal action of channels and creeks. These are broad and nearly horizontal and are dissected by numerous tidal channels and creeks. The fluvio-tidal and tidal landforms are depositional landforms and have distinctive accretion features described below.

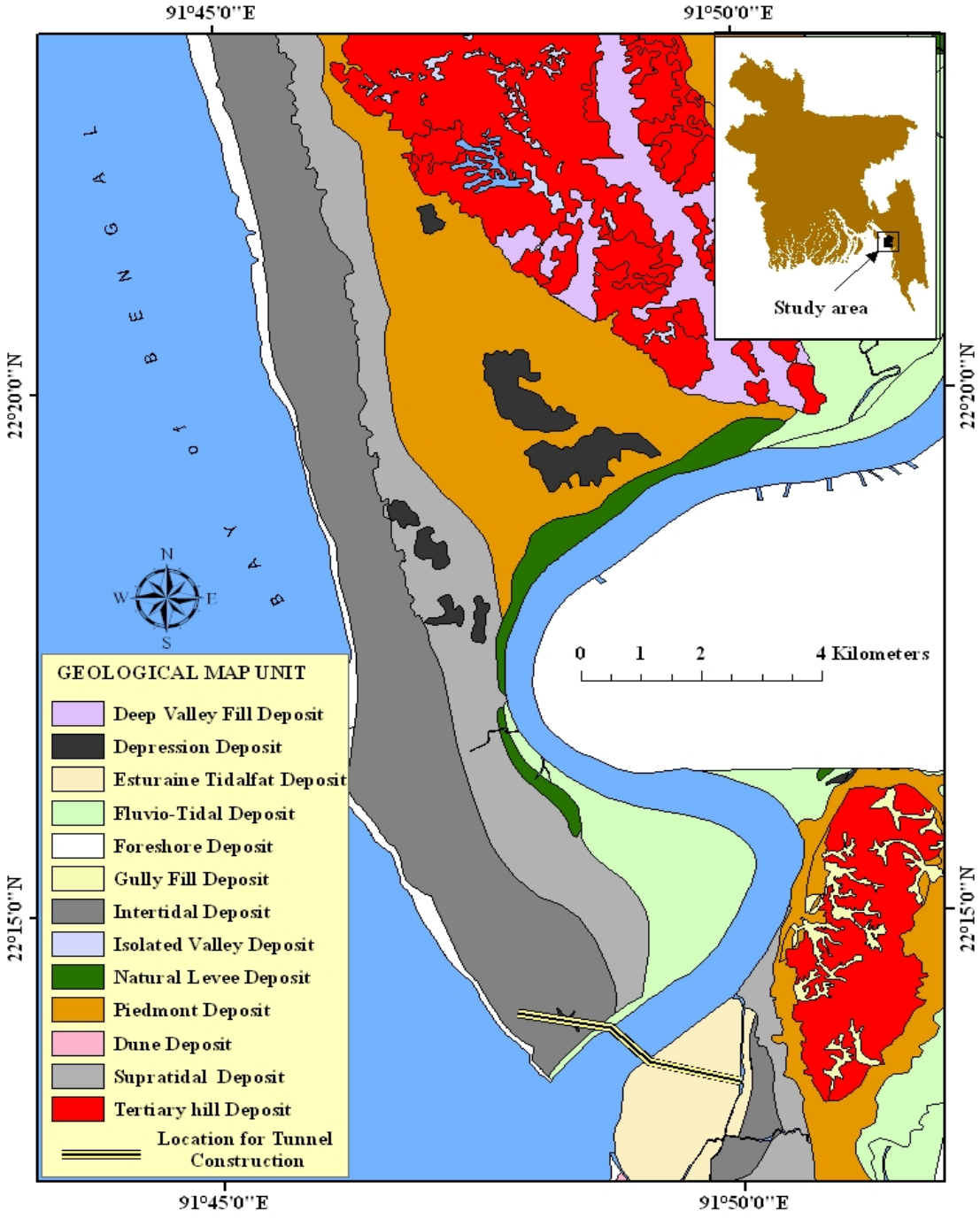


Figure 5.4.2.1-1 Geological Map Units of Chittagong Area (Based on Landsat TM 2010)

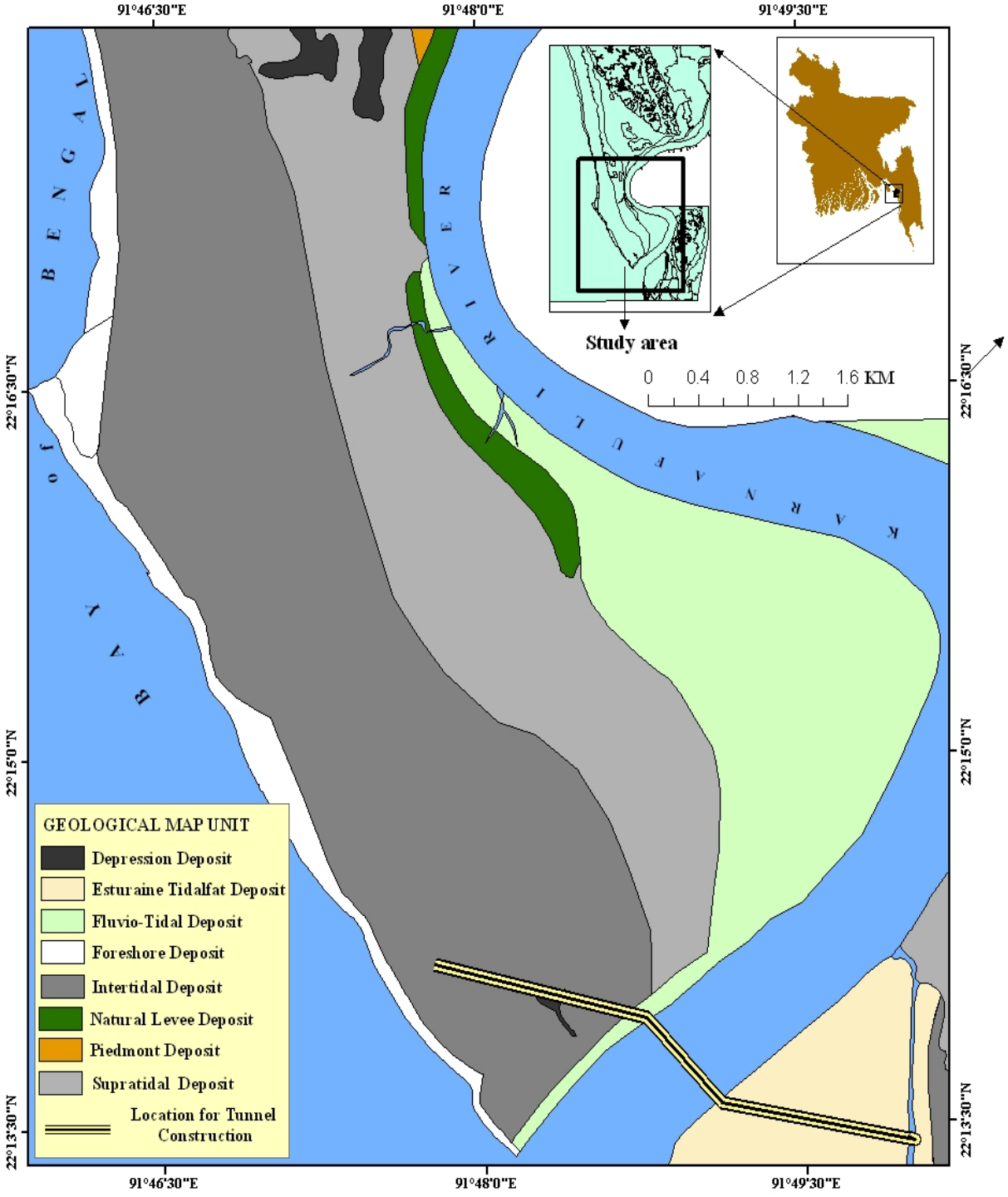


Figure 5.4.2.1-2 Geological Map Units in the Investigated Area with its Surrounding (Based on Landsat TM 2010)

Intertidal Deposit

These deposits occupy the areas between mean low- and mean high-tide levels. The unit is flat and very gently slopes towards the coast exhibits lower elevation than the adjacent supra tidal flat and piedmont area and dissected by a series of tidal creeks. Sediments deposited in this unit are mainly by vertical acceleration

due to inundation of flood tide twice daily. These areas are generally dissected these creeks act as an inlet and outlet of these areas. Deposits of this unit commonly vary from silt clay to clay (mud) of grey to dark grey in colour. Biogenic activities are prominent and organic shells are found scattered. Mangrove forest grows randomly. Clays/silt clays are sticky, moderately oxidized and oxidation along roots. The sediments are non-calcareous and acidic in nature. Mud cracks are common feature in this unit. Most part of the right bank side of the proposed tunnel falls under this category.

Supra-tidal Deposit

The deposit between mean high water level and mean high spring water level can be termed as supra-tidal deposit. These areas normally flat and broad, developed as an elongated body between alluvial fans and inter tidal flats and occupying the inter distributary areas dissected by tidal creeks and channels. Sediment depositions in these areas are due to flooding during exceptional tide related to oceanic depressions or any other abnormal phenomena and tidal action in rainy season. The deposited sediments are dominated by finer materials, generally clay to silt clay. Sediments are grey to light olive grey in colour, moderately sticky and moderately compact. In the satellite images this area is represented by dark to black colour which is for the mangrove forest. The sediments are non-calcareous and acidic in nature.

Estuarine Tidal Flat Deposit

These deposits are identified at the mouth of the Karnaphuli River between Middle Island and Outer Bar and are recognized as the estuarine tidal flat deposits. During the high tide time the areas belong to this unit is inundated that eventually reduced the width of mouth of the river due. The outer Bar at the mouth of the river and the estuarine tidal flat are developing very fast due to deposition of suspended sediments brought by the river. The surface of the unit is flat, ripple marked and barren. Here tidal processes dominated over the fluvial processes. These flats are present at the mouth or along both sides of the tidal channel and inundated by tide twice a day. In various imageries it shows grey, medium grey to dark grey in colour with smooth texture and distinguished by its shape and position at the mouth and adjacent to strong tidal channels. Lithological composition is dominantly of coarser-grained lag deposits with fines (clay to silt clay) at top. The left bank side of the proposed tunnel lies under estuarine tidal flat deposits.

Foreshore Deposit

In the study area, foreshore has developed as narrow fringes at the boundary of coast known as beach deposit also. Living and dead shells or fragmentary shell materials and current as well as wind ripples are present on the beach surface. Deposits of the foreshore are mostly composed of sand having grey appearance, fine to medium-grained, angular to sub-angular and moderately sorted. Sand is composed of about 65-70% quartz, 20-25% black minerals, 2-3% mica and others. Most of the Patenga beach and beach around the mouth of the Karnaphuli River fall into this unit. Part of the foreshore deposits in the investigated area is characterized by moderately dark tone and mainly consists of clay. Most of the beaches in south of the Patenga area falls into this unit.

Sand Dune

Sand dunes are hillocks or low hills of wind blow or drifted sand. Along the beach and the Karnaphuli River mouth where sands are available at the surface, sand mounds and ridges have formed due to wind action are mapped as sand dune. In the field these are very narrow and little elevated elongated unit between the beach and sea. Bright light whitish tone in the photographs is distinctive, Probable sediment type is sand. Dunes have gentle dipping towards the lower tidal flat and comparatively steep dipping towards the sea.

Fluvio-Tidal Deposit

Sediment deposition belong to this area is due to combined effect of both fluvial and tidal action. Dominant sediment composition is clay with silt clay which is grey to dark grey in colour. The sediments are acidic in nature. During the flood, huge sediments settle, mainly silt with medium-grained sand. Sand is brownish to yellowish grey. The area is fertile, sweet water is found away from the river. This area is suitable for population and is moderately vegetated. Adjacent to the Karnaphuli River, the unit is extended in north–western part of Boalkhali. Besides north-western part, most of the area of Patia is considered as Fluvio-Tidal plain. This area shows grey to light grey colour in the images and vegetation shows a particular trend which is the sign of river shifting. Peat layers are present within the sediments.

Natural Levee

This map unit is wedge shaped ridges of sediments deposited along the concave bank of the river. The natural levee along the river Karnaphuli is not that prominent, however a wedge along the Strand Road in the port area is identified as natural levee which grades into abandoned point bar. In the field it is difficult to identify the levees which gradually grades into point bar. The physical state of the levees in the area facilitated development of early industrial belt along the river. The levee top is rarely flooded, it is flat on the top and about 5 km in length and its width varies from 300 to 700 m. This unit shows light to medium grey tones and coarse texture in aerial photographs. It is distinguished by elongated shape and their position along river. Natural levees have identified in eastern part of Chittagong City. This unit consists of clayey silt and sandy silt.

Depression

Depressions are the deepest part of the study area which is usually covered with water throughout the year and occasionally dry during the winter season. In aerial photographs it shows dark grey tone with smooth but sometimes patchy texture. Here drainage pattern is irregular and density is coarse. Clay, organic clay, peaty clay and peat are found here.

Gully Fill

A gully is a small channel produced by the running water on slope of hilly terrain. Along the edge of hilly terrain several gullies of dendritic patterns have formed due to head ward erosion by running water. Gullies are developed across the bedding plan, these are perpendicular to the strike direction. This unit shows dark grey tone with smooth texture in aerial photographs. Drainage pattern of this unit is dendritic and is identified by its tone and position. The gully deposits are mixture of sediments and rock fragments derived from adjacent hills.

Deep Valley Fill

Any hollow or low lying land between higher ground (hills) usually traversed by flood water are termed as valley. Valley fill are the unconsolidated sediments deposited by any agent so as to fill or partly fill a valley. The valleys are parallel to regional trend of the fold. The deposits filled in the valleys are mixture of fragments derived from the adjacent beds. This unit shows light to medium grey tone with smooth texture in aerial photographs and distinguished by its linear shape and position between elevated hills. The valleys are composed of mixture of sediments and rock fragments derived from adjacent hills underlain by clay deposits.

Isolated Valley

Hilly terrains consist of hills and valleys. Normally valleys are interconnected for the drainage of water. Some valleys are not well connected where sediments from surrounding hills have been deposited. This unit shows very light to light grey tone with moderate texture in aerial photographs and distinguished by its tone and position in the hilly terrain. These are isolated mainly found in the sharp top of hilly terrain of the region. Sand and silt sand are the main sediment types of this unit.

Piedmont Plain

The Piedmont deposits are generally found in the wide valley areas of hilly terrain and are covered with an apron of sedimentary debris. Flow directions in the piedmont slopes are transverse to flow directions in the adjacent valley floor and forms sharp break of slope at the foothills. Piedmont plains are differing from the adjacent fan in term of elevation and texture. These are more elevated than the alluvial fan and have comparatively coarse texture. The slope of this unit varies from 3 - 5° and the unit is never flooded. The deposits are poorly sorted medium to fine sand underlain by clayey. Lithologically this map unit is characterized by admixture of sand, silt and clay having variegated colours.

Tertiary Hill Deposit

The Tertiary Hills occupy the eastern extremity of the mapped area and elongated approximately parallel to the coast although the area. The western flank of the Folded Flank is dissected with a regional fault known as Sitakund Fault, allowing depositing the piedmont and tidal sediments. The hills are blanketed with weathered sediments of Dihing Formation of Pleistocene age and are underlain by Bokabil, Tipam and Dupi Tila formations of Early Miocene, Mid. Miocene and Plio-Pleistocene age respectively. The sedimentary deposits are consisted mainly of alternation of shale, sandstone, siltstone and occasional conglomerate beds.

The northwest or right bank flank of the proposed tunnel falls under fluvio-tidal and inter tidal deposits and southeast or left bank part lies under estuarine tidal flat deposit **(Figure 5.4.2.1-2)**.

5.4.2.2 Structure and Tectonics

Structurally, the folded belt of greater Chittagong and Chittagong hill tracts comprises a series of parallel to sub- parallel arcuate elongated, ridge form, box like, high amplitude and variable width of doubly plunging folds (**Figure 5.4.2.2-1**). Most of structures are more or less longitudinally faulted and have maximum throws near the anticlinal culminations and plunge down and disappear

towards the peridinal extremities, though magnitude of faulting generally increases with the increase in intensity of faulting to the east (Guha,1978).

Bangladesh constitutes a major portion of the Bengal Basin, which is located at the head of the Bay of Bengal. The Bengal Basin covers an extensive area of northeastern part of the Indian plate, which includes Bangladesh and parts of the adjacent Indian states of west Bengal, Tripura and Assam. Bangladesh forms about three fourths of the Bengal Basin, which is bounded on the west by the Indian Platform, on the north by the Precambrian Shillong Massif, on the east by the Arakan Yoma folded belt system and on the south; it plunges in to the Bay of Bengal.

The Chittagong Hill Tracts is situated in the south eastern part of Bangladesh which represents the major portion of the folded flank of the Bengal Foredeep and is named as eastern Chittagong folded subzone of the internal zone of the Bengal Foredeep. The folding of this area started during the third movement of the Himalayan Orogeny and attained its present configuration with the concomitant emergence of Indo-Burman range. The Chittagong Hill tracts constitute the western foothills of the Indo-Burman range.

Bengal Foredeep may further be subdivided into two zones (Guha, 1978): 1) Frontal subbelt (Western zone) comprising relatively narrow box like anticlines Separated by wide, flat synclines with internal simple structural elements; 2) An inner mobile sub belt (Eastern zone) consisting of comparatively tight, linear with steep flanks and with complex faulted internal structures. The present study area, Chittagong City lies in the western marginal part of the Chittagong Hill Tracts within the folded part (Eastern Folded Flank) of the Bengal Foredeep of the Bengal Basin. The development of the Bengal Foredeep is directly related to the development of Himalayan Mountains in the north and the Arakan Yoma Hill Range in the east due to the north and northeastern collision of Indian plate with Eurasian Plate and Burmese plate respectively. Folds of Chittagong and Chittagong Hill Tracts are situated near the eastern edge of the Indian plate. An attempt has been made to interpret the mechanism for the formation of the folded belt of Chittagong and Chittagong Hill Tracts in the light of Plate Tectonic theory.

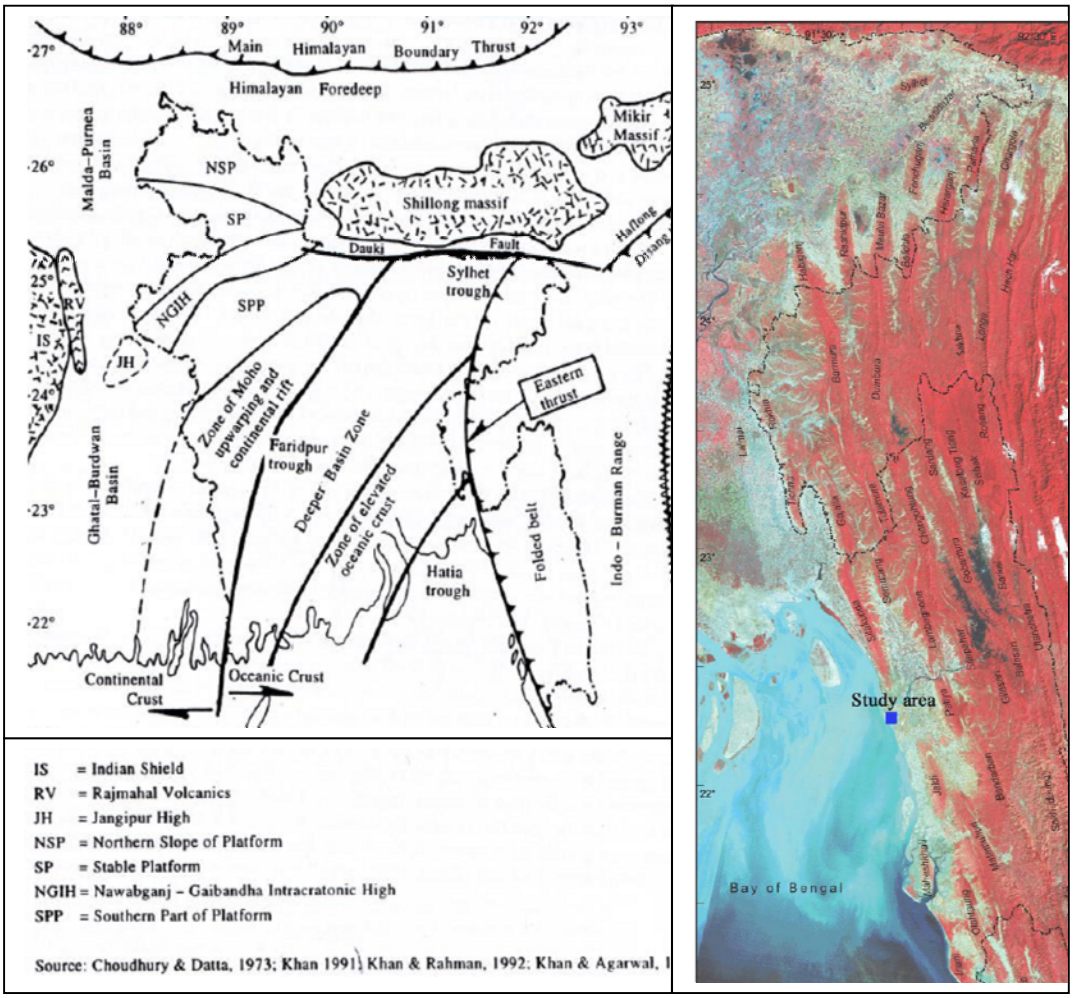


Figure 5.4.2.2-1 Tectonic Map of Bangladesh and Adjoining Areas

According to Curray and Moore (1971), the present relative plate motion between the Indian and Eurasian plates is apparently in a northeast, southwest direction at rate of convergence 5 to 6 cm per year. This movement is evidenced by the seismic activities in the plate boundaries and is confirmed by the studies of paleomagnetism of rocks and oceanic magnetic anomalies. The Indian plate being subducted and has been underthrusting the Burmese plate in the east and Tibet plate in the north. The underthrusting of the Indian plate has also been supported by the study of local mechanism solution for some earthquakes in the northeastern India and Burma. The movement of the Arakan subplate (bounded by the Ninety East Ridge and covering the eastern and the southeastern part of the Bangladesh) has been suggested to cause the formation of folds of the eastern flank of the Bengal Basin.

No active fault has been identified in and around the project area. The northwest-southeast trending lineament line crosses the left bank i.e. Anowara flank of the proposed tunnel **(Figure 5.4.2.2-2**). While fault is an active phenomena regarding plate movement, lineament has no motion and less vulnerable to earthquake response.

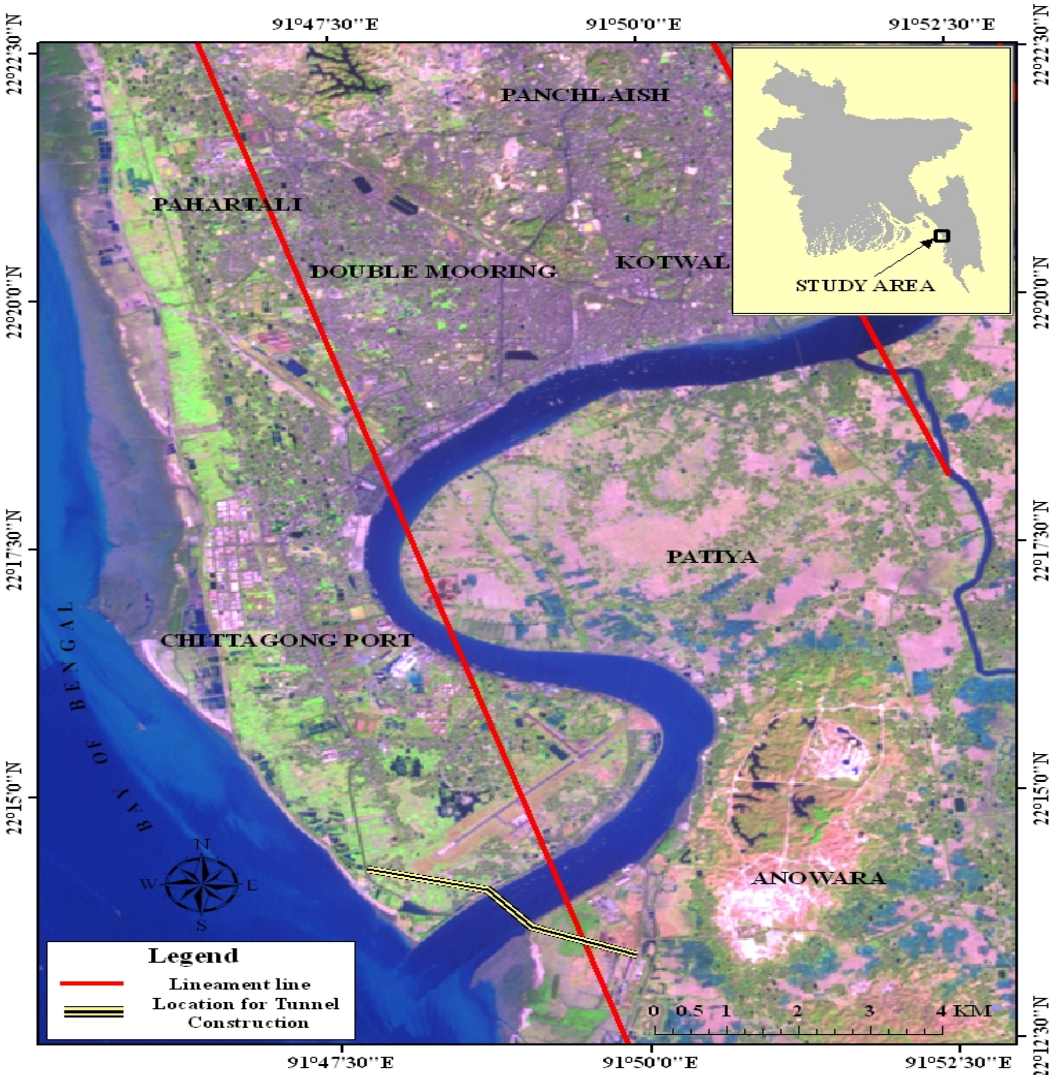


Figure 5.4.2.2-2 Map of Chittagong Area Showing the Major Lineaments

Damage to constructions caused by earthquakes occurs as a result of permanent deformation to the movement areas, ground vibrations, triggering landslides, causing tidal waves etc. The magnitude of earthquake occurred in the area in recent past ranged between 4.3 and 6 MB. No surface folding or faulting was identified in and around the project area. However, Bangladesh lies in one of the most active tectonic region of the world where three major plates i.e. the Indian plate, the Tibet sub-plate and Burmese sub-plate are colliding and thrusting against each-other. On the other-hand, the earthquake epicenter in Assam is very close to Bangladesh, therefore, measures in designing any structure is recommended.

In order to restrict damage as far as possible, considerable efforts need to be made to limit areas at risk and divide them into earthquake zones, to research the relationships between subsoil properties and the effects of earthquakes on constructions, influence of dynamic processes on the stability of natural slopes and earth structures, to determine measures to increase the resistance of constructions to counteract the risk they face, to clarify the causes taking consideration of earthquake forecasts and their control. Damage to constructions caused by movements along active fault zones are very difficult and extremely expensive to prevent by means of construction measures. The best method is to

find the potential fault zones and to keep them as free as possible from constructions.

The project area is located in the seismic zone-II of Bangladesh seismic map **(Figure 5.4.2.2-3)** where the earthquake factor Z is considered as 0.15. The N values and grain size distribution of the area indicate that the sub-surface material is susceptible to liquefaction during earthquake.

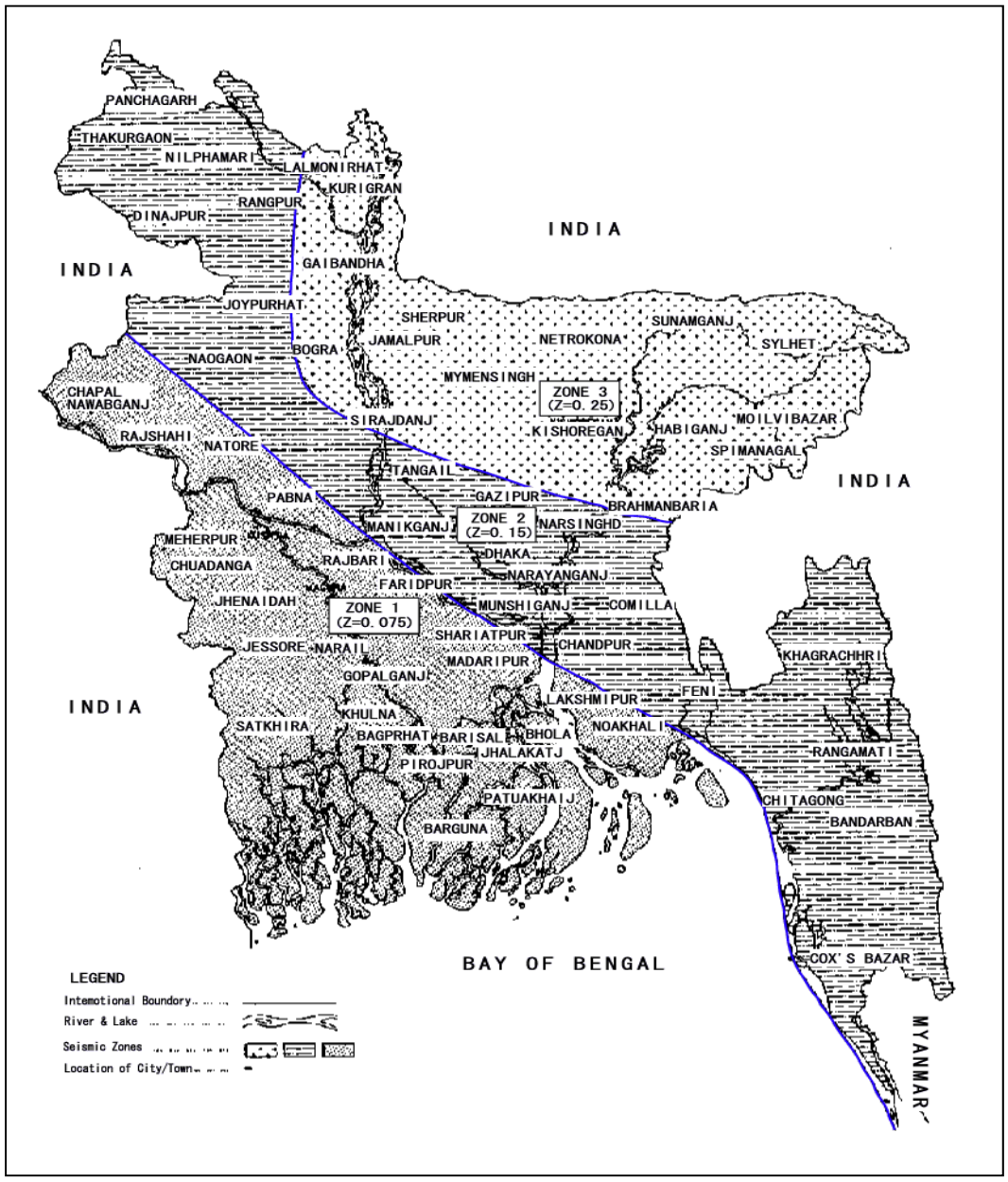


Figure 5.4.2.2-3 Seismic Zoning Map of Bangladesh

5.4.2.3 Stratigraphy and Subsurface Sedimentary Sequences

The geomorphology and stratigraphy within the project and surrounding areas are similar indicating flood plain deposit. Tertiary sediment belongs to the northern part of the study area. Tertiary sediments are mainly exposed at surface and the

relief is high in this area. For understanding and presenting subsurface sedimentary sequences and aquifer system in and around the project area, lithologic cross-sections and 3-D diagram have been drawn based on available lithologic logs down to the depth of about 300 m (**Figure 5.4.2.3-1**).

The hydro-stratigraphy of the area down to the investigated depth is very complex and lithology is variable within very short distance and depths. In general the section can be divided into three hydrostratigraphic units e.g. aquifer, aquitard and aquiclude. Sand is considered as an aquifer, aquitard and aquiclude are used for silty clay and clay respectively. Two aquifers are observed in the boreholes of the section down to the studied depth of 300m but their horizontal correlation is not exists due to horizontal and vertical discontinuity of aquitards. The inter layering of clay and sand may be the result of transgression and regressing that took place during the quaternary period.

Four aquifer units observed in the southern part and two aquifer units observed in the northern part. All the production well strainers for city water supply situated at the deep aquifer of the sections. Coastal aquifer system belongs to the southern part of the study area. Quaternary sediments are mainly exposed at surface. The hydrostratigraphic units are not continuous laterally and their depth and thickness is highly variable as well. Maximum thickness (about 45 m) of the aquifer is observed near the bank of Karnaphuli River. Therefore upper aquifer in the vicinity is expected to be connected with river bed of Karnaphuli River.

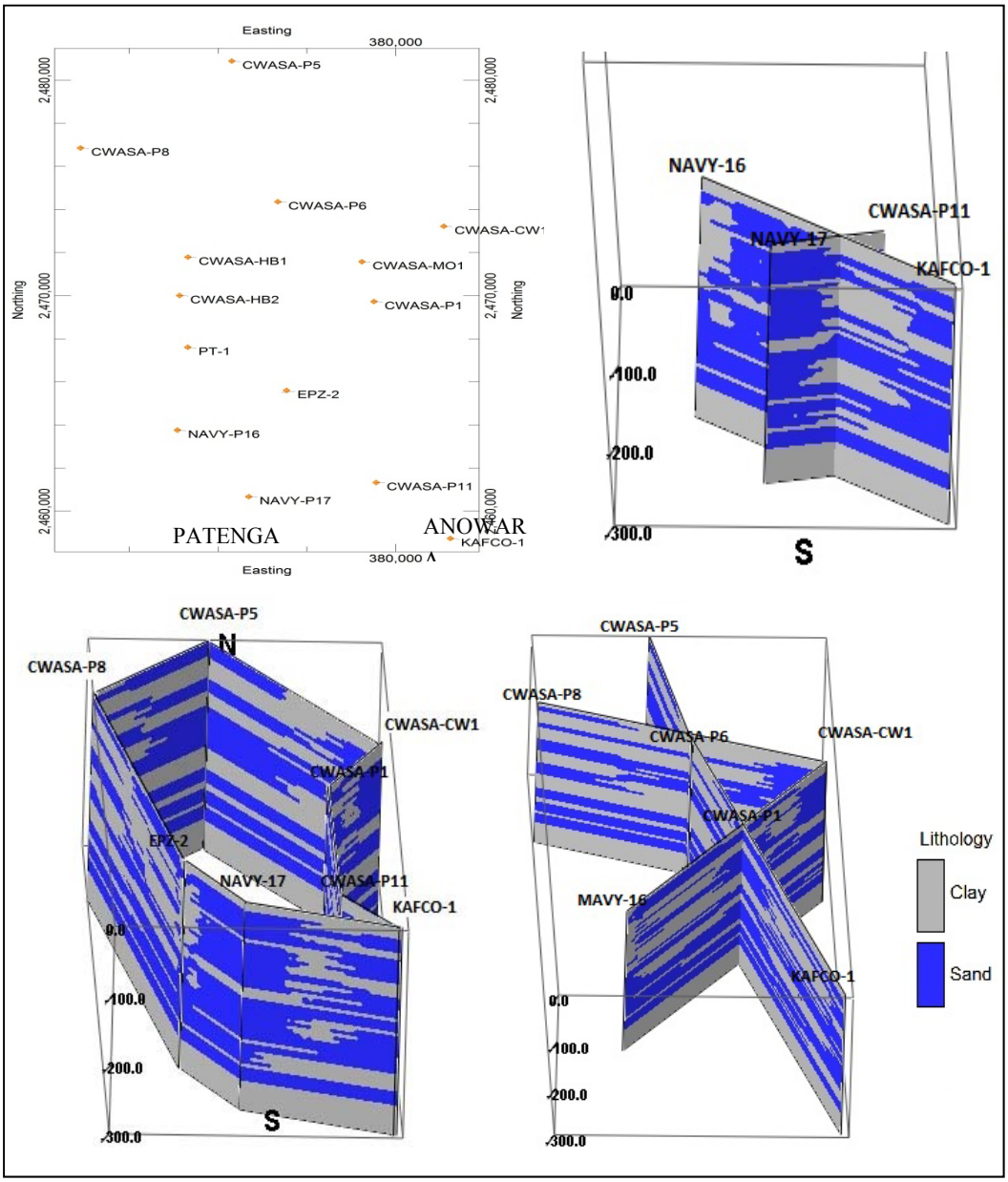


Figure 5.4.2.3-1 Lithologic Diagrams of Chittagong City – Anowara Area Down to the Depth of 300m Based on CWASA and other Logs

5.4.2.4 Hydrogeologic Setup

Hydrogeology of the area is tectonically and structurally controlled. There are systematic and locally predictable changes in the patterns of aquifer geometry. Steep gradient and high sediment supply are characterizing the area that was uplifted rapidly as a result of tectonics compression. Conversely, the sides of the flood plain are systematically filled upwards and are marked by a preponderance of muddy over bank deposits. This resulted in poor to fair aquifer condition with varying piezometric level or head having a relatively low to very low permeability. The thickness of the floodplain deposits is not well known but more than 250-300 m, as individual wells have been drilled to this depth. However, it is generally believed that the depth is considerably greater. Layers of coarser grained sediments occur at greater depths.

Suitable groundwater condition in most part of the Bangladesh is indicated by high rainfall and flooding in monsoon period and geological setting of the country. At present aquifers belong to semi-consolidated to unconsolidated fluvio-deltaic sediments of Miocene. Except the Dupi Tila Sandstone Formation formed in the Plio-Pleistocene age, while others are too deep for ground water extraction. Hilly regions of the country (18% of Bangladesh) are exceptions. The flood plains of the major rivers, active and inactive delta plains of the GBM Delta complex occupy 82% of the country. Major aquifer system belongs to the Late Pleistocene to Holocene sediments in these regions. The groundwater condition of the Chittagong City Corporation area can be divided into two zones (Tertiary zone and coastal zone) based on surface geology, topography, geomorphology and available borelog data of CWASA, BWDB. Each zone has individual aquifer system.

5.4.3 Geotechnical Investigation

Seven (7) boreholes were drilled to the depth of 45.0 to 81.0 m. Boreholes were arranged (1-2m outside the tunnel body as possible) along the tunnel axis on either left or right side in the pattern of "Z". Percussion method was adopted in drilling the borehole after driving a 120 mm diameter casing pipe. Both disturbed and undisturbed soil samples were collected from the boreholes using split spoon and Shelby tube samplers respectively. Disturbed soil samples have been extracted at 1.5 m depth intervals, which have duly been classified in situ and lithological logs were prepared for all boreholes. Undisturbed soils were collected from cohesive strata. Undisturbed samples were collected in order to perform certain laboratory tests which eventually help to evaluate the bearing capacities as well as geotechnical observations..

A cross-section is drawn down to the depth of 80 m with the borehole lithological logs, boring conducted within the project area under the study (**Figure 5.4.3-1**). The lithological section indicates that continuous fine to medium sand encountered from 10 and 20 m till the investigated depth of 90 m in the right and left banks respectively. Clay and silty clay layers overlies this sand unit. The aquitard is not clear below the entire section of the river bed which also depicts the hydraulic connectivity between river bed and aquifers. From all the lithological sections it can be assumed that tunnel may be constructed within clay and silty clay unit on both sides the river and within sand formation below the river bed.

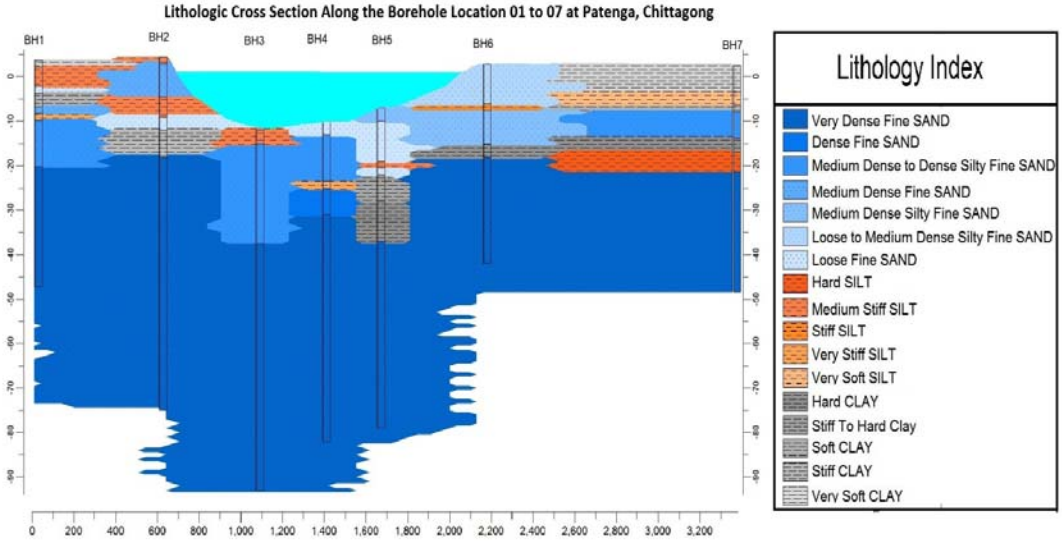


Figure 5.4.3-1 Subsurface Lithological Section based on Borelogs of Geotechnical Investigation

5.4.3.1 Standard Penetration Test (SPT)

Standard Penetration Test (SPT) is a simple method to test the density of coarse grained soils in the boreholes. SPT were executed at 1.5 m interval in all boreholes with the simultaneous collection of the disturbed soil samples. 63.5 kg hammer was used with fall height of 750 mm. The cone was driven 450 mm under the base of the borehole and the number of blows for each 150 mm was recorded. The number of blows for the last 300 mm was added. The following correlation has been found for granular soil. Standard Penetration Test was executed to determine the N values of soil strata and for collection of disturbed samples. The N-value indicates useful criteria with regards to consistency of cohesive soil and relative density of cohesionless soil.

High N values between 50-55 i.e. very dense (**Table 5.4.3.1-1)** condition of sub-soil has been recorded below the depths of 28, 26 and 45 m in the right bank, left bank and below the Karnaphuli River respectively (**Figure 5.4.3.1-1)**. However N-values of 31-50 i.e. dense condition were observed between 25 and 45 m from ground level below the river bed. Mainly four types of soil/sediment layers were detected based on engineering properties, such as, very soft to soft clay, medium stiff to very stiff non plastic silt, medium dense to dense silt fine sand and very dense fine sand. The clay in the upper surface is generally soft, the clay encountered 20 m deep below surface on both sides of the river and 15-20 m deep below river bed shows stiff to very stiff in nature (**Table 5.4.3.1-1**).

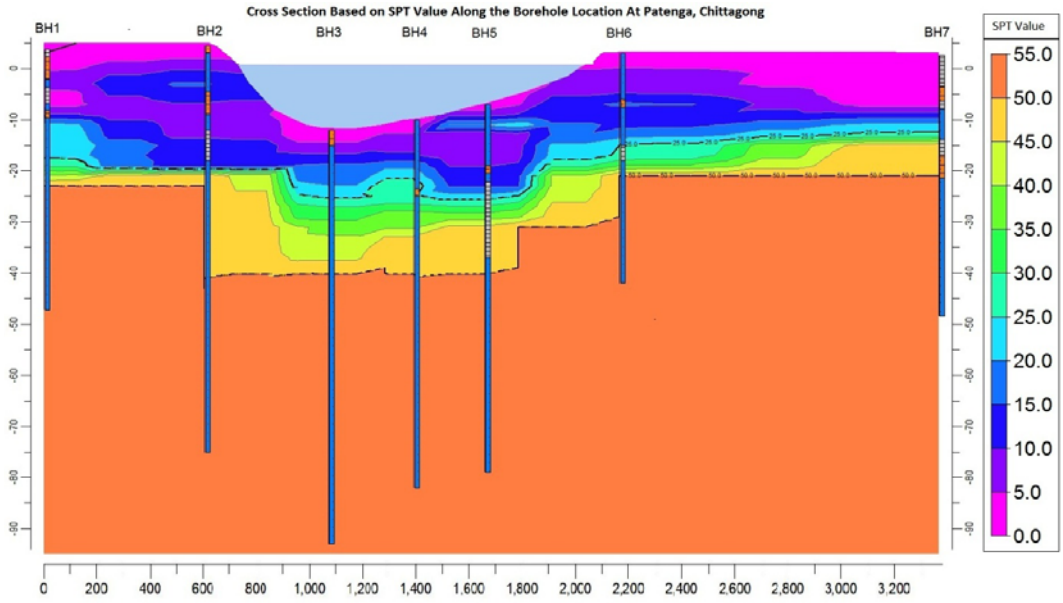


Figure 5.4.3.1-1 Profile of N-values of Sediment Strata Obtained from SPT along Boreholes

N – Value	Consistency	Unconfined Compression Strength (qu) tsf
0-2	Very Soft	0-15
2-4	Soft	15-35
4-8	Medium	35-65
8-15	Stiff	65-85
15-30	Very Stiff	>85
>30	Hard	

Table 5.4.3.1-1 Relation of N-value with the Consistency and the Unconfined Compression Strength of Cohesive Soil (ASTMD, 1586/2487)

N – Value	State of Density/ Compactness	Relative Density (%)	Friction angle Ø (°)	Unit Weight (pcf)
0-4	Very loose	0-15	28-30	70-100
5-10	Loose	15-35	30-34	90-115
11-30	Medium	35-65	34-40	110-130
31-50	Dense	65-85	40-50	110-140
>50	Very dense	>85	>50	130-150

Table 5.4.3.1-2 N and Ø relation to relative density for non-cohesive soil

5.4.3.2 Laboratory Tests

Engineering laboratory tests of soil samples reveal that the moisture content of the top layers of soil varies from 20 to 44 %. The liquid limit of the top layer of the cohesive soil varies from 34 to 44% and the plastic limit of the top of the cohesive soil varies between 23 and 33%. Based on the performance of unconfined compression strength test, the value of cohesion varies from 28.5 to 30.0 kPa. Based on the performance of direct shear test, the value of internal friction varies between 23 and 26 degree.

5.4.4 Groundwater Investigation

5.4.4.1 Aquifer Condition and Groundwater Status of the Study Area

In the coastal plain aquifers groundwater condition is highly variable with the possibility of saline water intrusion. The development of main and composite aquifers in upper aquifer system is limited only in isolated fresh water lenses. The erratic occurrence of small fresh water pockets at depth is reported all over the coastal belt. Confined coastal aquifers can contain fresh water even though overlying aquifers are salty. The Pliocene sediments form the deep aquifer in the coastal belt and occur at depths ranging from 30 m near the foothills to 300 m beneath the offshore islands. This is confined by overlying clay sequence which protects the fresh water from saline water (BWDB-UNDP, 1982).

The major subsurface lithological units of the area are Recent and Pleistocene sands and clays, silt and clays and sand and clays respectively. There are unconformable relations between the two depositional phases. The flood-plain deposits covering the older rock formation of Tertiary age probably constitute one large semi-confined to confined aquifer system. Although unconfined condition does exist, the aquifer system becomes more semi-confined to confined with increasing depth usually. The encountered hydro-stratigraphic units depicted a moderate to low hydraulic conductivity indicating major portion of the aquifer composed of fine-grained particles. The recharge to the upper aquifer occurs from the vertical percolation of rain and floodwater and by horizontal inflow from the surrounding areas. The deeper aquifers are the down deep extension of strata outcropping in the Chittagong Hill Tracts and in the coastal belt i.e. Pliocene sediments exposed in the escarpment hills of the coastal plain (BWDB-UNDP, 1982). Because of the seaward sloping of coastal plain strata deep aquifers are recharged in inland areas (GSB, 1978) and eastern hill ranges is the potential region for recharge to coastal deep aquifers. Tipam, Dupi Tila and Dihing formations below and recent alluvium of the area has good water storage potentiality. The slow upward movement of water from these aquifers may contribute water to the Holocene aquifers. The potentiometric surfaces are deeper in the hills whereas in flood plain it is close to the surface.

The potentiometric surface of middle and deeper aquifers in the vicinity of Karnaphuli River is at same level that reveals hydraulic connection of these two aquifers (Zahid et al., 2003). Hence the possibility of leaking of saline water from upper unconfined aquifer is less under sustainable condition. However, the situation is complicated in the study area. The present groundwater head of the city area is below the mean sea level that is also observed from the contour map (**Figure 5.4.4.1-1** and **Figure 5.4.4.1-2**). The maximum depth of groundwater table in dry season is 16-17 m and it is 9-10 m during monsoon. The groundwater heads of the city area is declining continuously due to huge withdrawal for municipal demand with little seasonal fluctuation of water table **(Figure 5.4.4.1-3**). In the surrounding aquifers the water heads are above the mean sea level and very close to the surface with significant water table fluctuation, mainly due to groundwater irrigation in dry season. However, the groundwater head generally regains equilibrium condition in monsoon.

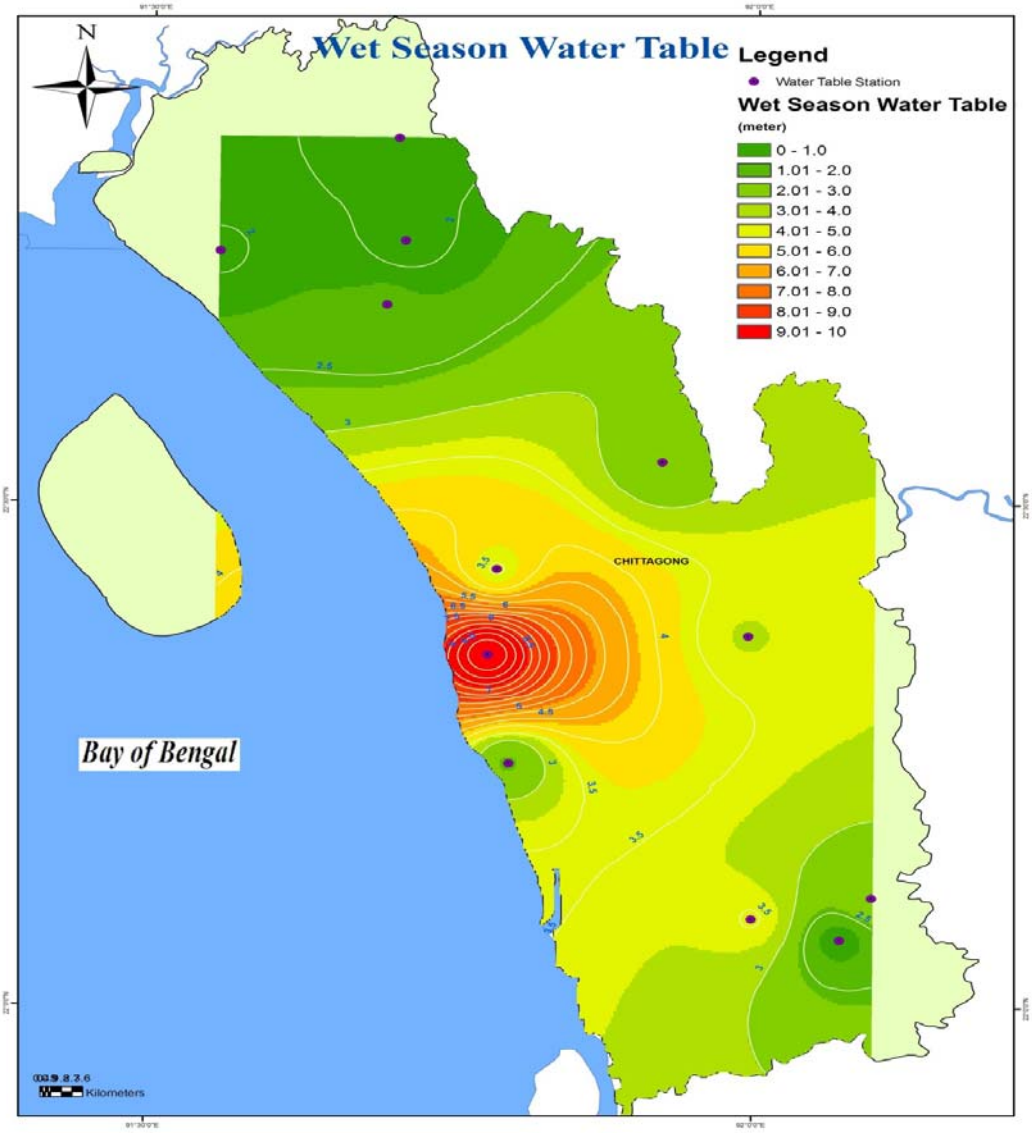


Figure 5.4.4.1-1 Groundwater Table Contour Map of Chittagong District Area During Wet Season (2011)

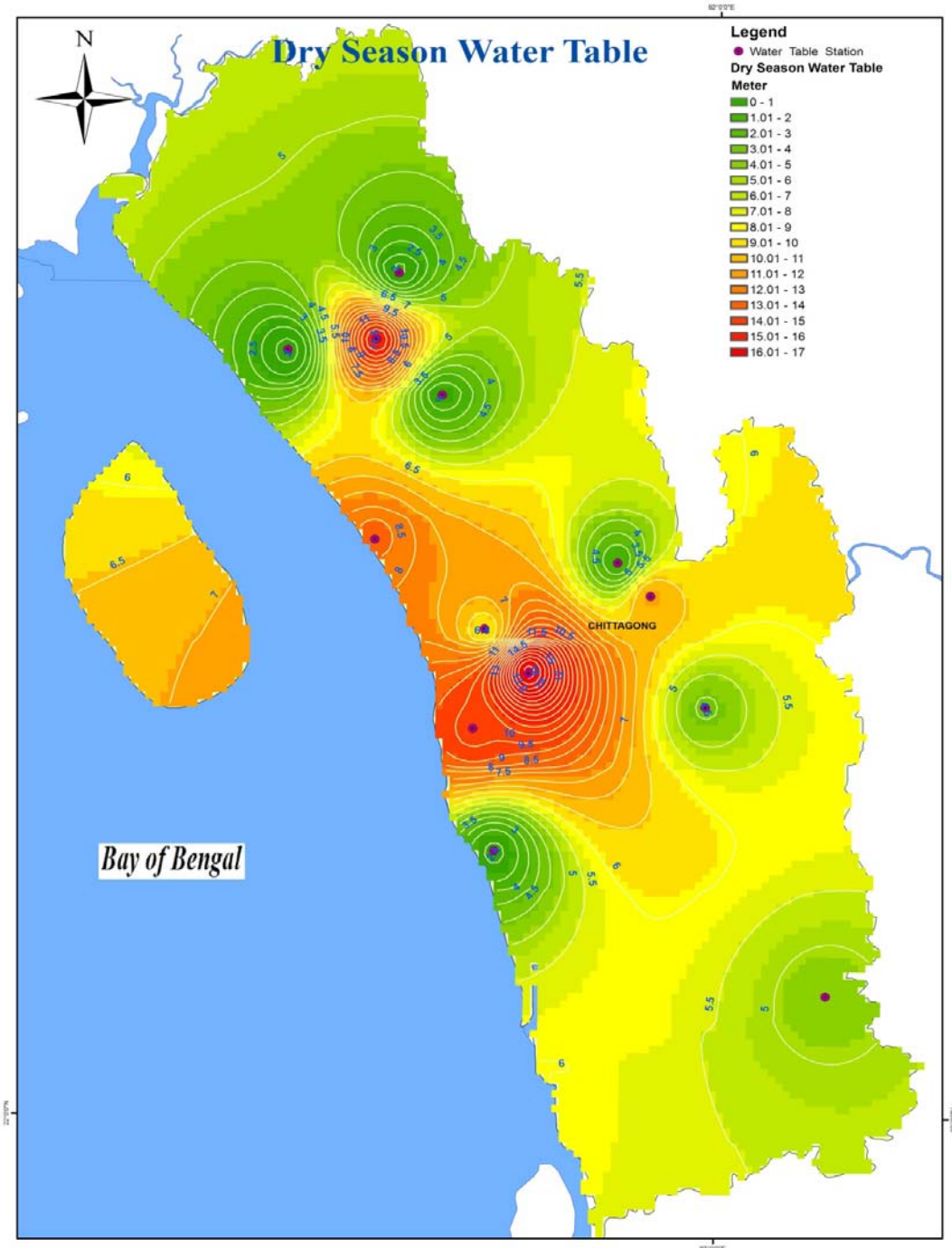


Figure 5.4.4.1-2 Groundwater Table Contour Map of Chittagong District Area during Dry Season (2011)

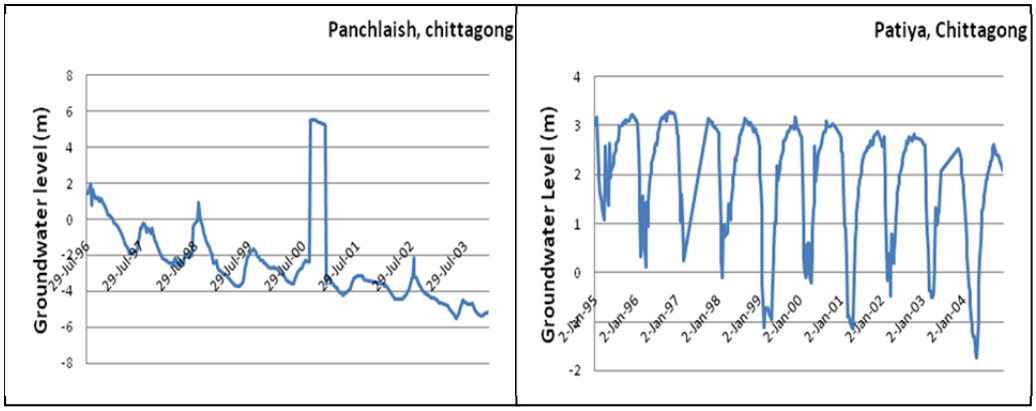


Figure 5.4.4.1-3 Groundwater Level Hydrograph in the Vicinity of Chittagong Study Area

5.4.4.2 Groundwater Control/Dewatering

As groundwater levels might be higher in most places than the base level of the proposed tunnel, excavations would require a dewatering system. For cut and cover construction, the dewatering systems will depend on the permeability of the various soil layers exposed. Lowering the water table outside the excavation could cause settlement of adjacent structures, impact on vegetations, drying of existing wells, and potential movement of contaminated plumes if present. Precautions should be taken when dewatering the area outside the excavation limits. Within the excavation, dewatering can be accomplished with impermeable excavation support walls that extend down to a firm, reasonably impermeable stratum to reduce or cut-off water flow.

Impermeable retaining walls such as interlocking steel sheet pile wall or diaphragm wall could be placed into deeper less permeable layers, such as silty clay or clay, to reduce groundwater inflow during construction and limit draw-down of the existing groundwater table. In some areas, a pumped pressure relief system may be required to prevent the bottom of excavation from heaving due to unbalanced hydrostatic pressure.

Pumping wells can be used to temporarily lower the groundwater table outside the excavation support during construction; however this may have environmental impact or adverse effects on adjacent structures. To minimize any lowering of the water table immediately outside the excavation, water pumped from the excavation can be used to recharge the water bearing strata of the groundwater system by using injection wells. Provision would have to be made for disposal of water in excess of that pumped to recharge wells, probably through settlement basins draining to storm drains.

Dewatering an excavation may lower the groundwater outside the excavation and may cause settlements. The lowering of the external groundwater can be reduced by the use of slurry walls, tangent or secant piles, or steel sheet piles. Adjacent structures with a risk of settlement due to groundwater lowering may require underpinning. Furthermore, where lowering of groundwater exposes wooden piles to air, deterioration may occur. Contaminated material may need to be placed in confined disposal facilities.

5.4.4.3 Water Quality

Both river water samples and groundwater samples from upper aquifers were collected from Patenga and KAFCO end and important chemical and physico-chemical parameters were analysed and presented in **Error! Reference source not found.**. Except arsenic, iron and ammonia-nitrogen, all other analysed parameters of groundwater samples are found within the allowable limit for drinking water set by the Department of Environment (DoE), Bangladesh. The concentration of excessive arsenic is harmful for human health, but might not have negative impact for construction materials. In river water samples chloride content is detected higher than average content in fresh water. However, concentration of none of the parameters might have any negative impact for tunnel construction.

Sl. No.	Pameters	Unit	Groundwater		River Water		Bangladesh Standard for Drinking Water
			Patenga	KAFCO	Patenga End	KAFCO End	
01	Latitude	N	22°13′56.18″	22°13′42.55″	22°13′51.95″	22°13′48.17″	
02	Longitude	E	91°48′18.69″	91°49′08.04″	91°48′31.16″	91°48′49.46″	
03	Depth	Ft	60	40			
04	pH	_	7.7	7.3	8.2	8.2	6.5-8.5
05	Salinity	‰	-	-	18	18	-
06	Dissolved **ra**Oxygen	mg/l	-	-	4.2	4.5	6
07	Total Suspended Solid	mg/l	-	-	480	340	-
08	Total Dissolved Solid	mg/l	-	-	19.35	22.7	1000
09	Manganese (Mn)	mg/l	0.05	0.03			0.1
10	Arsenic (As)	mg/l	0.41	0.39			0.05
11	Chloride (Cl)	mg/l	0.53	0.36	532	355	150-600
12	Iron (Fe)	mg/l	1.21	0.98			0.3-1.0
13	Total Hardness as $CaCO_3$	mg/l	1.8	1.5			200-500
14	Ammonia-Nitrogen	µg/l	0.85	0.57	0.85	0.57	0.5
15	Faecal Coliform	mg/l	-	-			150-600
16	Total Coliform	mg/l	-	-			-
17	Oil and Grease	mg/l	-	-	1.028	1.854	0.01
18	BOD	mg/l /hr	-	-	0.62	0.71	0.2

Sl. No.	Pameters	Unit	Groundwater		River Water		Bangladesh Standard for Drinking Water
			Patenga	KAFCO	Patenga End	KAFCO End	
19	COD	mg/l	-	-	4.88	4.75	4

Table 5.4.4.3-1 Analytical Result of Groundwater and Surface Water Quality

5.5 Hydrological Survey and Investigation

5.5.1 Scope

Hydrological survey and investigation will include mainly collection of hydrological data on water/tide level, discharge, cyclonic surge height, climatological data like rainfall, storm/wind velocity, temperature, humidity, sunshine hour, etc. The impact of relevant hydrological features on the proposed tunnel and approaches including average/ordinary water level and maximum water level at different point of alignment, surface water flow along the river, inundation and drainage, cyclonic surge height and magnitude of inundation will be analysed and assessed under different frequencies and return period. It also conducts hydro-graphic survey to collect river cross section and high flood level data to determine discharge for both wet and dry season as well as investigating the present condition and future plan of hydraulic facilities and flood control embankment at both banks of Karnaphuli River at the tunnel location.

5.5.2 Data Collection

Hydrological data, especially the yearly highest and lowest water level of Karnaphuli River, is available from Chittagong Port Authority.

Yearly highest and lowest water level data at station Khal – 18, Khal – 10 and Sadatghat was collected for the year 1980 to 2010. Data Analysis and Determination of Hydraulic Design Parameters

5.5.2.1 Design High Flood Level

To undertake the hydrological, the collected data was analysed with standard statistical methods and formulae. Results of the statistical analysis are summarized in **Table 5.5.2.1-1**

Return Period In years	Khal – 18 DHFL(mMSL)	Khal – 10 DHFL(mMSL)	Sadarghat DHFL (mMSL)	Tunnel Location (mMSL)
2.33	3.74	3.60	3.49	4.29
5	3.90	3.87	3.70	4.45
10	4.03	3.93	3.87	4.58
20	4.16	4.07	4.03	4.71
50	4.32	4.25	4.24	4.87

100	4.44	4.39	4.40	4.99

Table 5.5.2.1-1 Design High Flood Levels at Different Locations of Karnaphuli River

The suggested high flood level at the location of the proposed tunnel is determined by adding 5 cm. with the DHFL at Khal – 18 which is at 500m upstream to the location of the proposed tunnel.

Interestingly there occurs a reverse slope between the two stations, may be due to some hydrodynamic phenomena.

An addition of 0.50 meter is considered for tidal surges causing rise of DHFL at the location of proposed tunnel.

5.5.2.2 Design Peak Discharge

Normally stage-discharge station is not available so that design discharge could be determined by discharge frequency analysis. However "Slope-Area" method will be used to determine the high flood discharge based on surveyed cross section, assuming reasonable flood slope and roughness coefficient.

Considering the effect of cyclonic surges, the flow area has been determined by adding 1 meter with the computed DHFL of different return period.

However the effect of cyclonic surges is observed to be 2 meter (1991 cyclone) at the sea mouth. 25% of the observed value is considered because it is unlikely that cyclone of that magnitude will coincide with the DHFL.

5.5.2.3 Lacey's Required Waterway

The peak design discharge and required waterway for the return period of 20, 50 and 100 at the location of the proposed tunnel is shown in the **Table 5.5.2.3-1**.

Return period in years	Flow velocity m/sec	peak design discharge cumec	Required waterway
2.33	1.35	22,724.25	723.58
5	1.36	23,088.27	729.35
10	1.37	23,383.26	734.00
20	1.38	23,678.91	738.62
50	1.38	24,047.15	744.34
100	1.39	24,323.52	748.61

Table 5.5.2.3-1 The Peak Design Discharge and Required Waterway

5.5.2.4 Maximum Depth of Scour

Scour depth has been calculated using both the formulae stated above. The value of "silt factor" has been considered from the IRS Code, on the basis of soil boring result at the Karnaphuli River bed.

However it is considered that the required water way will not be constricted and hence the estimated maximum scour depth, using total flow, is -20.91mMSL for 100 years of return period, with absolute maximum level of scour depth as -21.03 mMSL.

Whereas the estimated maximum scour depth, using average intensity of flow, for 100 years of return period is 20.96 meter, from the DHFL i.e. the scoured bed level is at -15.97 mMSL, with absolute maximum level of scour depth as -16.02 mMSL.

The estimated maximum scour depth, using section wise intensity of flow, for 100 years of return period is 23.58 meter, from the DHFL i.e. the maximum scoured bed level is at -18.59 mMSL.

Hence the designer may consider the absolute maximum level of scour depth as -21.03 mMSL.

5.6 Seismic Characteristics of the Area

5.6.1 General

Seismic activities in history and distinguish the sections that are favourable, unfavourable or dangerous to the project in accordance with the seismic zonation of basic intensity of earthquake, for example, the specific location and activeness of the rupture need to be meticulously investigated where the alignment passes through and professional judgment should be in formulating design criteria with a view to protect tunnel and associated from earthquake of probable magnitude.

5.6.2 Review of Seismic Characteristics

5.6.2.1 Seismic Assessment for Bangladesh

The recent analysis of the seismicity, geodesy, and geology of the Bangladesh basin, based on both historical and modern records, points to the potential for large subduction earthquakes in the region because of its location along the same plate boundary that ruptured in the 2005 ‘Sumatra-Andaman Earthquake’ [3].

The Geo-tectonic map showing major tectonic elements of seismogenic interest in the eastern collision margin of the Indian plate (modified from geological map of Nandi, 2001) shows the alignment of the Padma Lineament (PL) along the river Padma [4]. (**Figure 5.6.2.1-1**, reproduced as presented below).

[3] Source: Subduction and Accretion across the Ganges-Brahmaputra Delta: Is it seismogenic? Leonardo Saber from LEDO University and Dr. Syed Humayun Akhter from Dhaka University, Internet.

[4] Source: Monograph of Faults and Seismogenic Fault Rupture in Bangladesh, Aftab Alam Khan, Bangladesh Earthquake Society Publication, 2005.

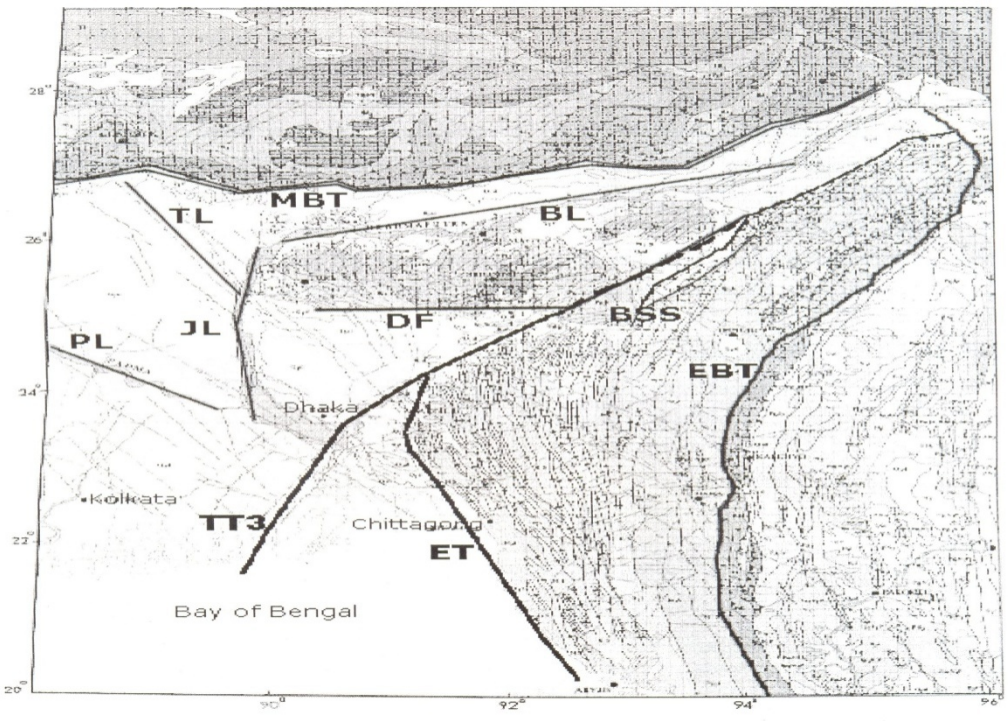


Figure 5.6.2.1-1 Monograph of Faults and Seismogenic Fault Rupture in Bangladesh

BUET made a Deterministic Seismic Hazard Analysis (DSHA) for Bangladesh by using McGuire (1978) and Boore (1993) acceleration attenuation expression to predict PGA. The PGA (in g) Contour Map of Bangladesh based on 10% probability of exceedance during 50-year return period shows PGA 0.15 using McGuire expression and about 0.11 using Boore expression. The value using 5% probability of accidence becomes 0.18 and 0.13 respectively [5]. Boore's expression is mainly applicable to rock while McGuire's expression is applicable for both rock and alluvium. Since the tunnel is an important structure, the minimum PGA value 0.18 corresponding to 5% probability of accidence considering 50-year return period may be tentatively selected for further evaluation during the detailed engineering stage.

The earthquake analysis will be done based on static analysis using the conventional procedures given in AASHTO Bridge Design Standards 2002 and BNBC'93. The results should be verified by the dynamic analysis. Then liquefaction potential using the actual subsoil properties including the grain size distribution should then be determined. The factor of safety of the liquefaction potential should be not less than 1.

Liquefaction analysis is a critical component of design as the bed material at the site is generally fine granular having little cohesive/adhesive properties. The liquefaction potential is the ratio between the maximum shear stress (caused by the dynamic shaking) and the effective vertical stress in the particular strata. The

[5] Source: Seismc Hazard Analysis of Bangladesh, M.A. Noor, M. Yasin and M.A. Ansary, Proceedings First Bangladesh Earthquake Symposium (BES-1), Dhaka, 14-15 December 2005.

types of foundation soil below barrage being generally loose granular without cohesion/adhesion, during earthquake particle suspension may occur from release of contacts between particles of sand below the barrage. The liquefaction potential must not be less than 1.

The design shall also consider the post-liquefaction deformation of the soil and its effect on the structure, if any. The objective is to bring back the liquefaction induced partially deformed structure back to service with some amount of repair and rehabilitation.

5.6.2.2 Seismic Assessment for the Chittagong Area

Chittagong has a long history of earthquakes. The greater Chittagong Hill Tracks districts experience tectonic movement in previous years. Tectonic movement in 2002 was measured 5.5 in Ractor scale which could be reflected on Karnaphuli River also. As its intensity was mild no damage or human casualty was recorded during occurrence. Mild to moderate unperceived movement are frequently felt in greater hilly region of India and Myanmar area.

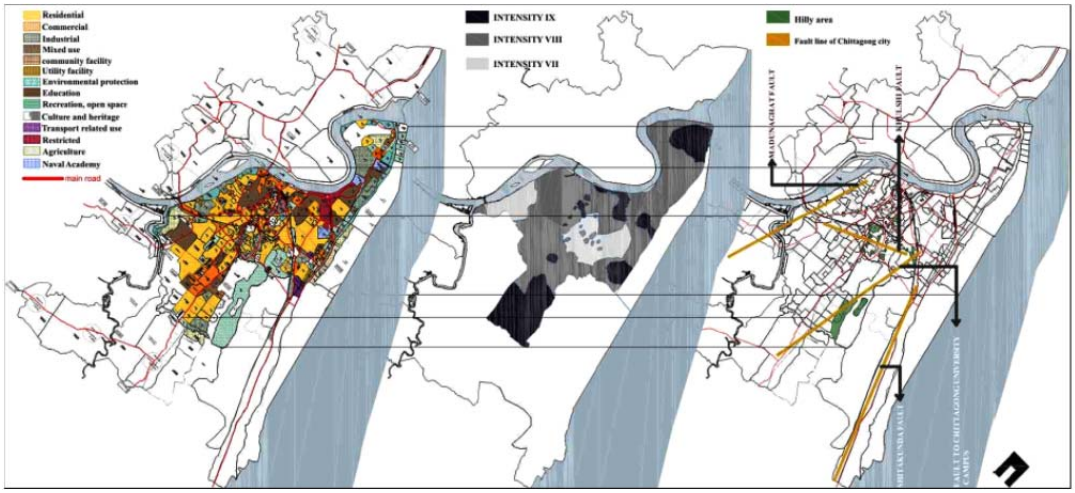


Figure 5.6.2.2-1 Seismic Hazard Zoning Map

During this long geological time the area has experienced a varied environment due to the transgression and regression of sea. The area occupies most of the plunge area of Sitakunda Anticline and the plungearea is cut by Sitakunda fault, Tiger Pass fault and Karnaphuli fault (Error! Reference source not found.) (Mominullah, 1978). It is also observed that the older sediments are severely jointed and fractured indicating dissipation of accumulated energy. According to the Global Seismic Hazard Assessment Programme (GSHAP) (Chittagong division is the most hazardous division in Bangladesh. Maximum peak ground acceleration (PGA) may be expected to be in the range of 0.24–0.48 g. The present geological condition indicates that the area is located in a zone where possibility of occurring earthquake is very high.

6. PRELIMINARY TUNNEL DESIGN AND CONSTRUCTION

6.1 Technical Criteria

(1) Design Criteria

The design criteria of expressway are recommended for Alignment C.

(2) Design Speed

Design speed of 80km/h is recommended for Alignment C.

(3) Number of lanes

Dual two-lane is recommended.

6.2 Selection of Construction Standard and Technical Specification

6.2.1 Selection of Technical Specifications

The preliminary design of this project is based on the following technical specifications:

(1) “A Policy on Geometric Design of Highways and Streets-2004, fifth edition”

(2) “Technical Manual for Design and Construction of Road Tunnel”

(3) “A Guide for Achieving Flexibility in Highway Design”

(4) “AASHTO Provisional Standards - June 2008 Edition”

6.2.2 Clearance and Cross-section

6.2.2.1 Clearance and Cross-section of Shield-driven Tunnel

(1) Dual two-lane shield-driven tunnel (without non-motorized vehicle lane and sidewalk)

Horizontal clearance: 0.7+0.5+2×3.65+0.6+0.7＝9.8m

Vertical clearance: 4.9m

Inner diameter of the tunnel: 10.8m

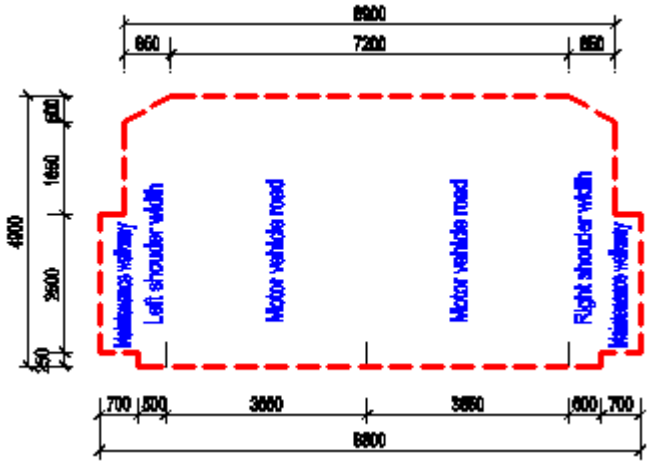


Figure 6.2.2.1-1 Clearance of Dual Two-Lane Shield-driven Tunnel (without non-motorized vehicle lane and sidewalk)

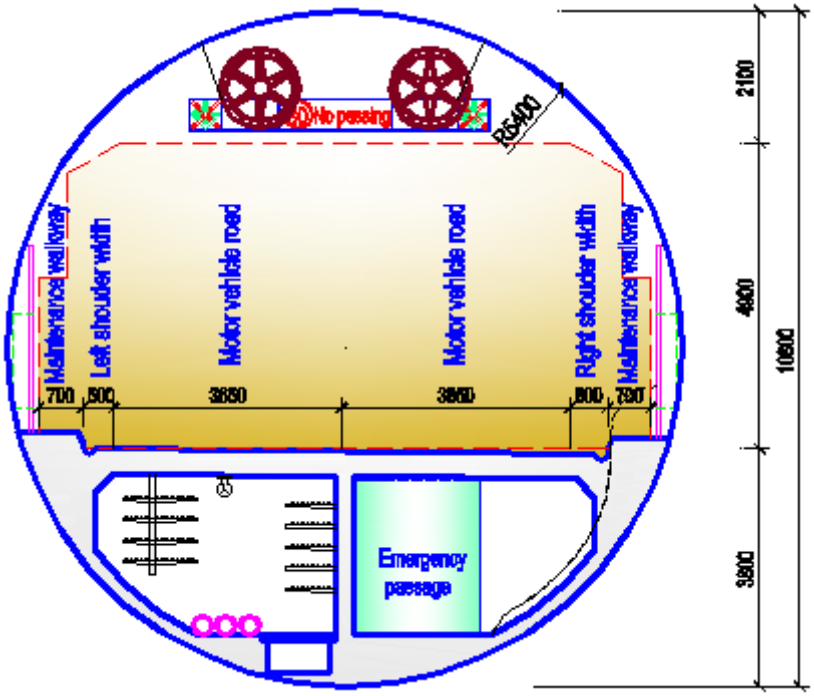


Figure 6.2.2.1-2 Clearance and Cross-section of Dual Two-Lane Shield-driven Tunnel (without non-motorized vehicle lane and sidewalk)

(2) Single-tube dual two-lane shield-driven tunnel (without non-motorized vehicle lane and sidewalk)

Horizontal clearance: 0.25+0.5+2×3.65+0.6+0.25＝8.9m

Vertical clearance: 4.9m

Inner diameter of the tunnel: 13.7m

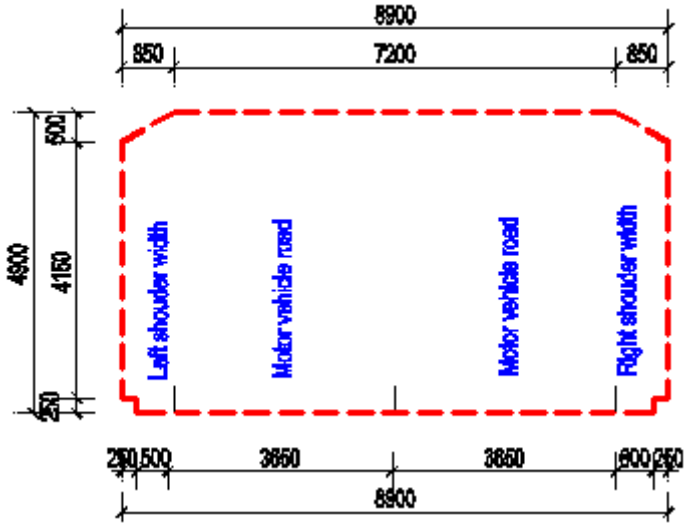


Figure 6.2.2.1-3 Clearance of Single-tube Dual two-Lane Shield-driven Tunnel (without non-motorized vehicle lane and sidewalk)

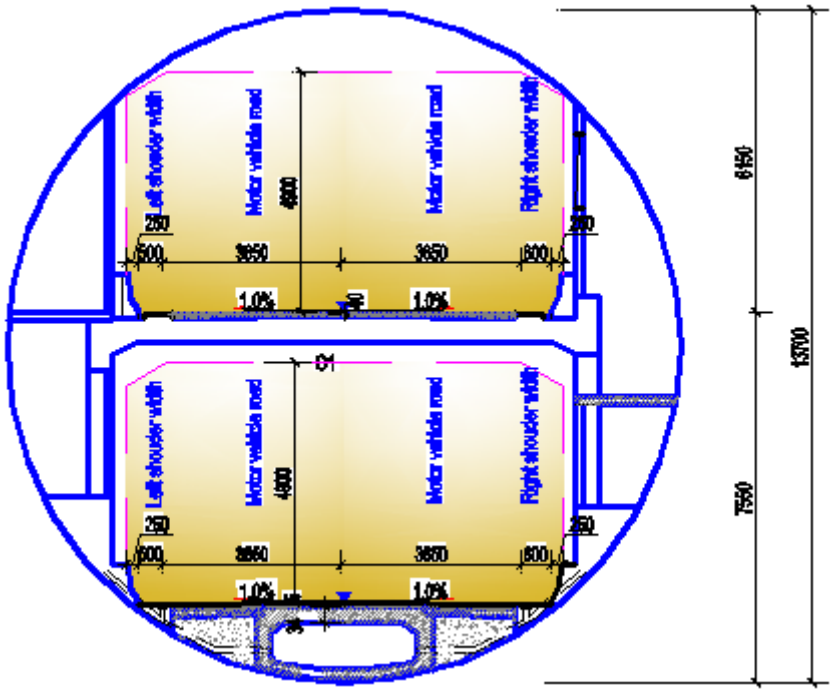


Figure 6.2.2.1-4 Cross-section of Single-tube Dual Two-Lane Shield-driven Tunnel (without non-motorized vehicle lane and sidewalk)

(3) Dual two-lane shield-driven tunnel (with non-motorized vehicle lane and sidewalk)

Horizontal clearance: 0.25+0.5+2×3.65+0.6+2.5＝11.15m

Vertical clearance: 4.9m

Inner diameter of the tunnel: 12.2m

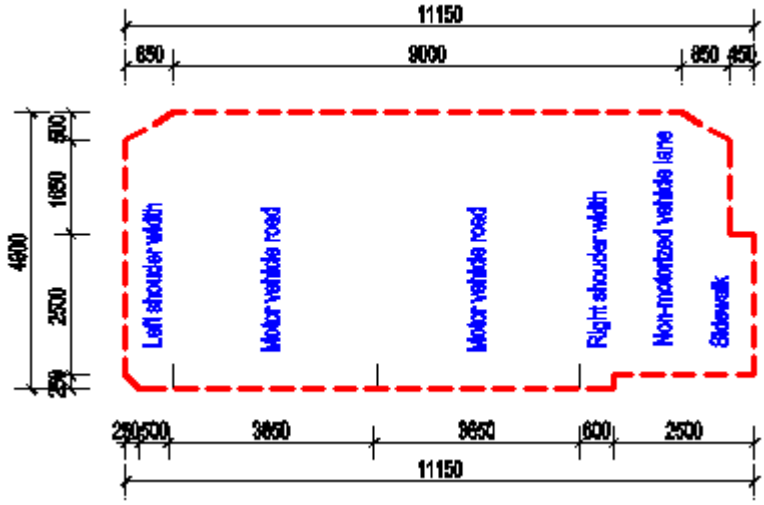


Figure 6.2.2.1-5 Clearance of Dual Two-Lane Shield-driven Tunnel (with non-motorized vehicle lane and sidewalk)

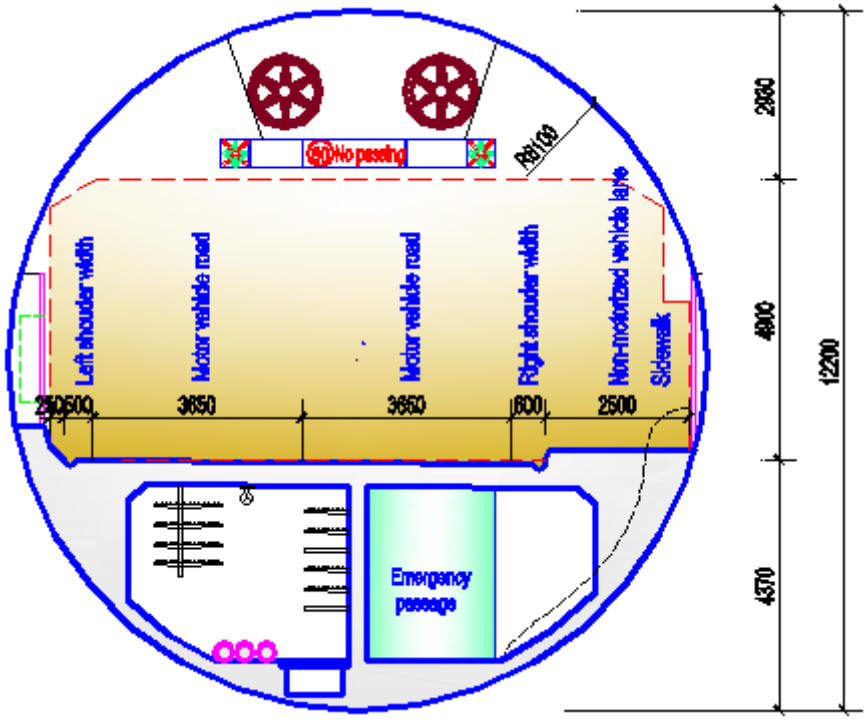


Figure 6.2.2.1-6 Clearance and Cross-section of Dual Two-Lane Shield-driven Tunnel (with non-motorized vehicle lane and sidewalk)

6.2.2.2 Clearance and Cross-section of Immersed Tube Tunnel

Dual two-lane immersed tube tunnel

Horizontal clearance: 0.25+0.5+2×3.65+0.6+0.25＝8.9m

Vertical clearance: 4.9m

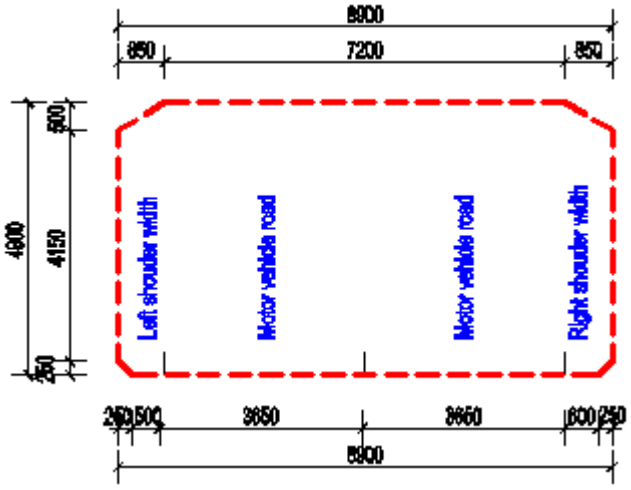


Figure 6.2.2.2-1 Clearance of Dual Two-Lane Immersed Tube Tunnel

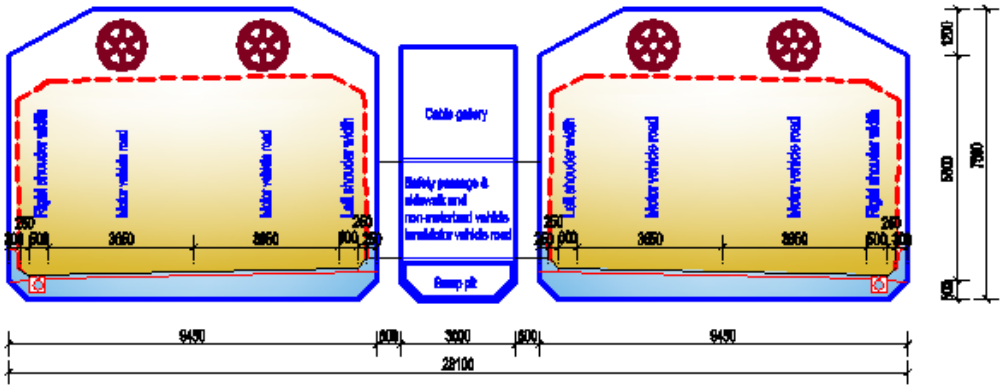


Figure 6.2.2.2-2 Clearance and Cross-section of Dual Two-Lane Immersed Tube Tunnel

6.2.3 Selection of Shield-driven Tunnel Section Type

Based on analysis, the above section layout with non-motorized vehicle lane and sidewalk is not recommended. Twin-tube dual two-lane tunnel (without non-motorized vehicle lane and sidewalk) is provisionally recommended at current stage.

6.3 Geological Profiles along Tunnel Alignment

The recommended Alignment C passes through the strata of very soft clay, medium stiff silt, loose fine sand, soft clay, medium dense fine sand, and very stiff sand, with a thickness of 1~3m; in deep buried landward section, it mainly passes strata of medium dense to dense silty fine sand, with thickness of 6～22m; and in river crossing section, it mainly passes through very dense fine sand. The strata of upper half section of tunnel along the alignment are medium dense to dense silty fine sand or stiff to hard clay.

6.4 Selection of Tunnel Construction Method

From comparison, the shield-driven method for the proposed tunnel alignment is superior over the immersed tube method in view of project applicability, environmental protection, impacts on the main traffic routes and significant enterprises and institutions on both bank sides, as well as impacts on relocation, flood prevention and navigation etc; therefore, the shield-driven method is recommended for this project.

6.4.1 Shield-driven Tunnel Scheme

6.4.1.1 Design Scheme of Longitudinal Section

The longitudinal section for Alignments A, B and C by shield-driven method is given in the figures below, respectively.

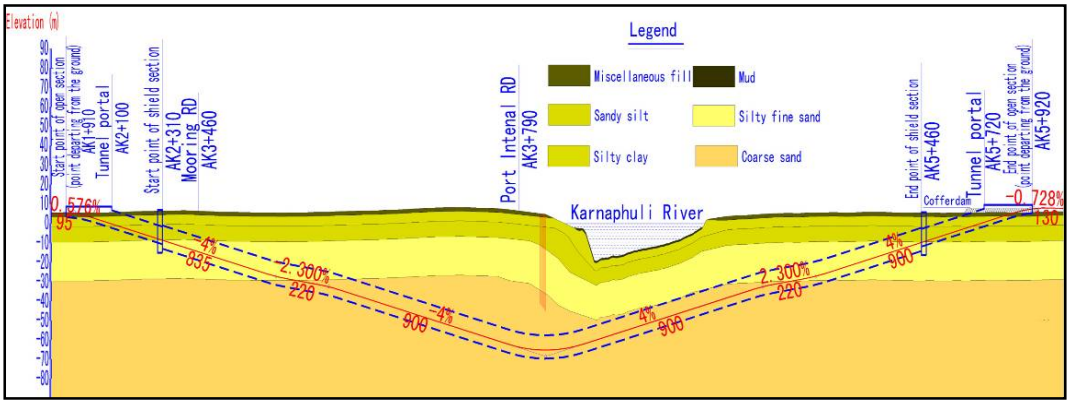


Figure 6.4.1.1-1 Longitudinal Section of Alignment A by Shield-driven Method

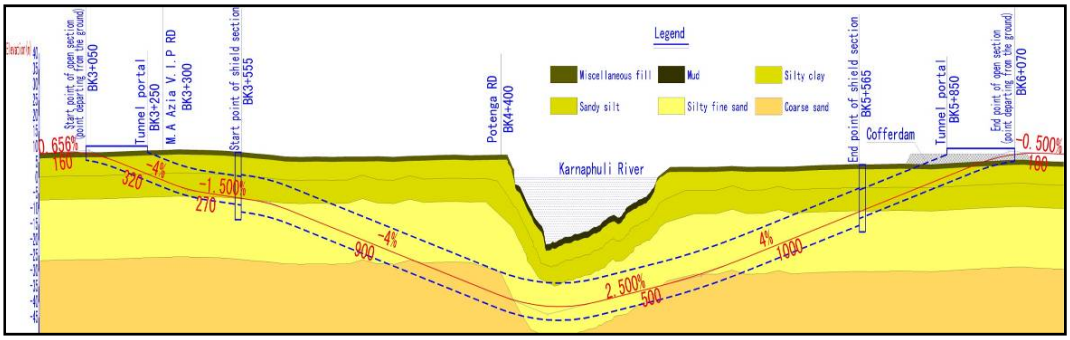


Figure 6.4.1.1-2 Longitudinal Section of Alignment B by Shield-driven Method

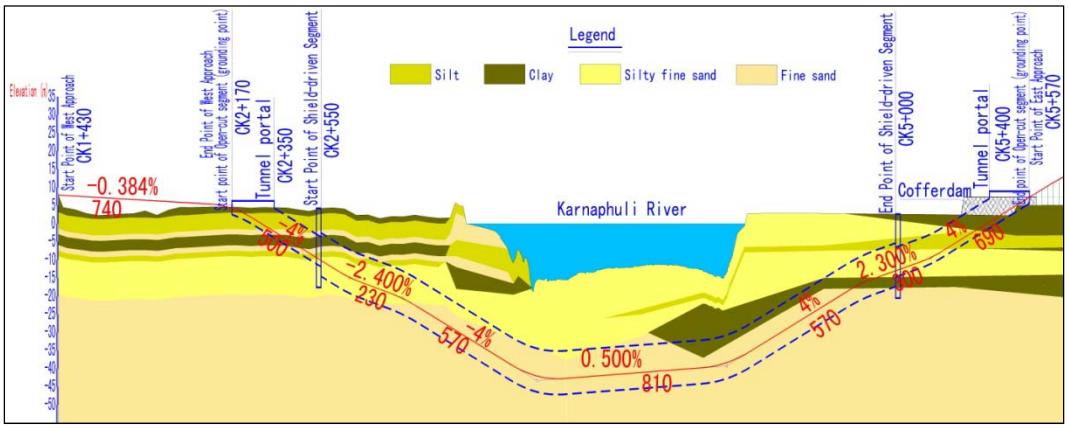


Figure 6.4.1.1-3 Longitudinal Section of Alignment C by Shield-driven Method

Comparison among alignments A, B and C based on project cost, construction conditions, geological conditions and construction difficulty that Alignment C is the best option.

6.4.1.2 Cross-section Scheme

In order to meet the requirements for disaster prevention and rescue, interconnecting passages between the left and right tunnels will be set up at a certain interval of around 600~700m, and the minimum distance between the two tunnels is considered as 1 time of the tunnel diameter.

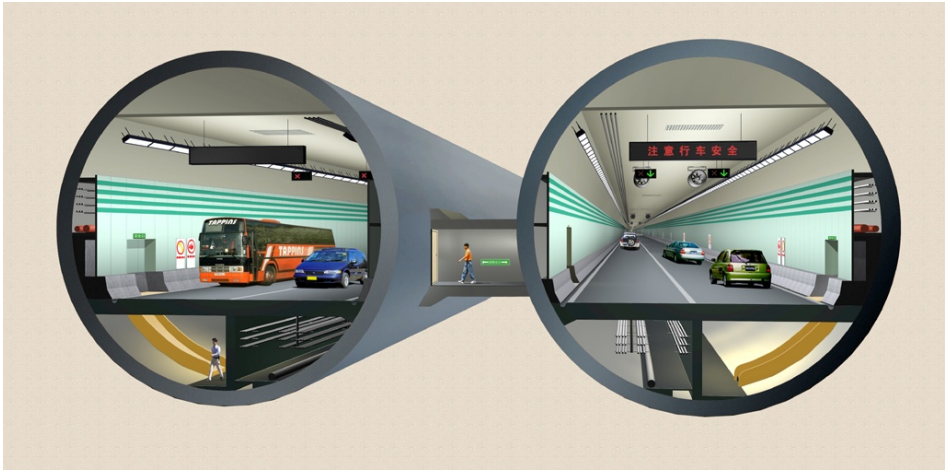


Figure 6.4.1.2-1 Cross-section of Twin-tube Dual-two Lanes Tunnel

Design of Tunnel Structure

6.5 Design of Tunnel Structure

6.5.1 Design of Shield-driven Structure

6.5.1.1 Design Principle

(1) The tunnel structure shall satisfy the requirements of construction, operation and earthquake resistance. In addition, it shall be safe, practical and cost-effective.

(2) The design working life of main structure shall last for 100 years with Class I safety grade and importance coefficient of 1.1.

(3) Chittagong is located in Seismic Zone II with the horizontal seismic zone coefficient of 0.15. Structural seismic design shall be conducted based thereon.

(4) Structure clearance, equipment clearance, safety evacuation and other function requirements as well as comprehensive construction errors shall be taken into consideration when designing the cross section of shield-driven part.

(5) Tunnel lining shall adopt flexible structure with certain rigidity. The deformation and joint opening shall be restrained and structural stress and waterproofing requirements shall be met.

(6) Calculation of structural strength and deformation shall be made for the tunnel structure in accordance with different service conditions of construction and operation period; crack width of structural components shall satisfy corresponding design requirements.

(7) In addition to the required strength and rigidity, the structural design shall also satisfy the requirements of waterproofing, corrosion resistance, safety and durability etc.

(8) Transversal calculation mode of lining structure shall be determined according to the actual working conditions such as strata status, lining structure features, etc. The joint efforts of lining and soil strata and the effect of assembly lining joints shall be considered.

(9) Reliable engineering treatment measures shall be taken for tunnel where load, structure or geological conditions may change, or deformation joints need to be set due to anti-seismic requirement, in order to ensure that no uneven settlement will occur at the structures on both sides of deformation joints. Configuration and spacing of deformation joints shall satisfy structural waterproofing requirements and anti-seismic requirements, etc.

(10) During structural design, the section structure shall satisfy the requirements of different load combinations and geological conditions etc.. Standardized lining types shall be used to facilitate unified manufacturing of fabricated lining.

(11) The section structure shall be designed such that during the advance of the shield-driven machine in medium dense to dense silty fine sand and very dense find sand, the section structure as the jack backseat could meet the longitudinal force transfer requirements.

6.5.1.2 Engineering Overview of Shield-driven Section

Shield-driven section starts from west bank CK2+550 and ends on east bank CK5+000 with the overall length of 2450m, with a maximum longitudinal gradient of 4% and a minimum horizontal curve radius of 1500m. The maximum overlaid soil of tunnel is located on east bank CK4+368.140 with a thickness of 30.908m. Flood level for a return period of one hundred years of 6.74m (MSL elevation, equal to PWD elevation of 6.28m) is taken as the design water level. The tunnel vault experiences maximum water pressure at CK3+554.359 with a water pressure of 0.414MPa.

The shield-driven section mainly passes through very dense find sand, and the strata of upper half section of the tunnel at some sections along the alignment are medium dense to dense silty fine sand or stiff to hard clay.

6.5.1.3 Lining Structure Design

(1) Inner diameter of the tunnel tube

The inner diameter of the tunnel tube is suggested as 1080 mm provisionally.

(2) Selection between single and double-layer lining

Single-layer lining is provisionally considered to be used for the shield-driven tunnel.

(3) Structural type of segment

Reinforced concrete plate-type segment is suggested as the lining segment for this project.

(4) Lining ring width and thickness

The width of a lining ring is determined as 2000mm, while lining thickness is determined as 500mm.

(4) Setting of lining ring taperness

Taperness is taken as 36mm and wedge-shaped ring is established as dual-surface wedge with unilateral wedge angle of 5′14.64″. The limit turning radius corresponding to such taperness is 655.556m, and the minimum radius of horizontal curve of this project is about 1500m.

(5) Selection of ring type

Common segment Wedge-shaped rings are recommended for the project.

(6) Ring separation scheme

In shield tunnel, segment separation form generally has two kinds: standard piece + adjacent piece +capping piece, or in equal division way. The following scheme is adopted for segment separation of this project: segment separation adopts the way of 5+2+1, i.e. there are in total 8 pieces, including 5 standard pieces, 2 adjacent pieces and 1 capping piece. Adjacent pieces and standard pieces are 46°57'23.48" while capping piece is 2/3 of standard piece, i.e. 31°18'15.65". Each longitudinal seam adopts 3 bolts and there are altogether 24 M36 bolts. 4 M30 bolts are for ring seam of capping piece while 6 M30 bolts are for the ring seam of adjacent piece and standard piece. Therefore, totally 46 M30 bolts are used. Only a kind of lining ring is used for fitting curve section to ensure assembly precision in curve section. Capping piece position will be adjusted according to the ring rotation during the assembly process and there are 8 assembly points of the last ring staggered joints, as shown in the figure below.

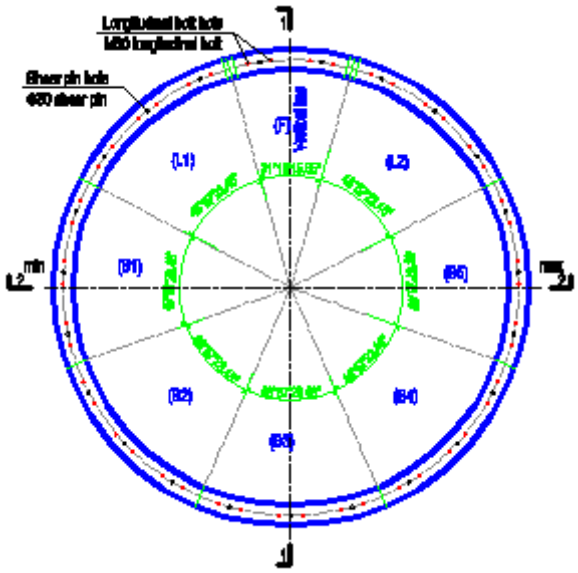


Figure 6.5.1.3-1 Scheme Diagram of Ring Separation

(7) Structure of ring seam and longitudinal seam as well as joint connection types

Mortise-free face connection pattern is recommended for this project.

Inclined bolt connection is recommended for both ring and longitudinal joints of segment. To improve precision requirements in segment assembly, positioning bar is set on the end surface of longitudinal seam and shear pin on the end surface of ring seam for auxiliary assembly.

(8) Engineering material of lining structure

Common lining ring is made of reinforcement concrete segments with concrete strength of C60 and anti-seepage grade of P10 or P12. Steel bar is in Grade HPB235 and HRB335 steel while steel is in Q235B. The performance grade of segment connection bolt is Grade 5.8, 6.8 and 8.8 and embedded parts adopt Q235B steel.

6.5.1.4 Design of Tunnel Cross Section

(1) Arrangement of tunnel cross section

The shield-driven section employs small diameter twin-tube, with each tube provided with bidirectional motor vehicle lanes inside. Each tunnel tube consists of two decks, an upper deck as motor vehicle lane and a lower deck as cable gallery and emergency passage. The lane deck, in addition to providing space for tunnel decoration, also provides space for equipment including road traffic signal lights, jet fans, device cabinets, loudspeakers, lighting sets, monitor cameras, leakage cables and sprinkler heads etc. Inside the lower deck, a partition wall divides it into two sides, one side is provided with various cables, fire water piping, and catch drains, the other side is used as the longitudinal emergency passage. On the partition wall one maintenance door is set every 1,000m.

Between the two circular tubes of the tunnel, an interconnecting passage is provided at each 700 m interval. In case of emergency in one tube, people can evacuate to the other tube through an interconnecting passage. Also, the rescue

personnel may perform a rescue activity in the vicinity by using these interconnecting passages. Inside each circular tube, an emergency exit and a slide are provided at each 250 m interval, connected with the emergency passage. Passengers and drivers may also reach the emergency passage by using these slides and evacuate in the longitudinal direction.

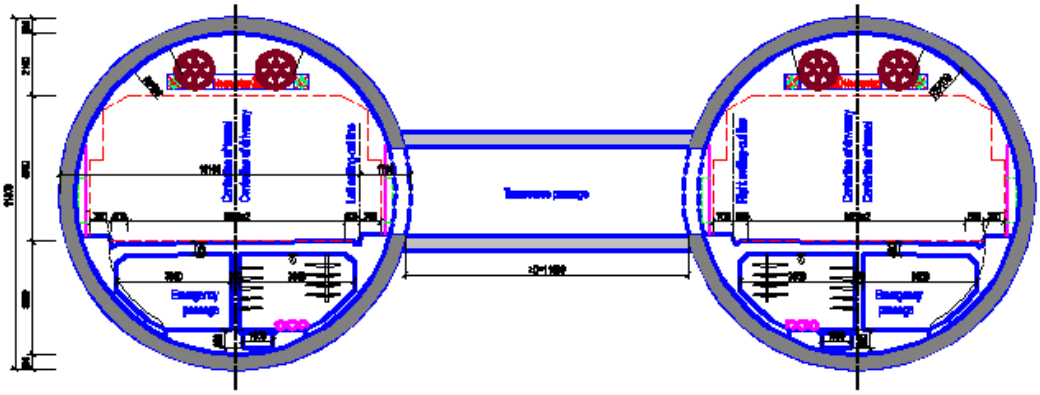


Figure 6.5.1.4-1 Cross Section of Shield-driven Section

(2) Internal structure design of tunnel

The lane slab inside the tunnel is C45 reinforced concrete slab with thickness of 400mm and the foundation on both sides of it uses C45 reinforced concrete pouring. The partition wall in the lower space is C35 reinforced concrete wall with thickness of 300mm. The inverted arch uses C25 plain concrete for filling.

6.5.2 Structural Design of Working Shaft

6.5.2.1 Design Principle

(1) Structure is Class I in safety grade and design working life is 100 years. The structural strength, rigidity and stability shall be calculated for all structures and components in accordance with the most critical load combination occurred in construction and normal operation period.

(2) Chittagong is located in Seismic Zone II with the horizontal seismic zone coefficient of 0.15. Structural seismic design shall be conducted based thereon.

(3) The allowable value of crack width shall be determined according to the structural type, application requirements and the local environmental conditions.

(4) Structural anti-floating shall be designed according to the full water buoyancy of maximum underground water level, and calculated according to the most critical condition. Anti-floating safety coefficient shall be no smaller than 1.05 while without considering side wall friction force and no smaller than 1.15 when considering side wall friction force.

(5) Safety grade of excavation pit works shall be determined according to the surrounding environmental conditions, excavation depth of excavation pit and retaining structure function; design of the excavation pit shall be conducted according to corresponding requirements.

(6) Design safety coefficient of excavation pit works is obtained by multiplying basic safety coefficient and additional safety coefficient.

(7) Reasonable retaining system shall be selected in design according to the design requirements of excavation pit.

(8) Strength, deformation, stability and seepage within and outside excavation pit shall be calculated for support structure.

(9) Retaining wall also serves as part side wall of main structure of working shaft and forms overlapped structure with lining wall to share force together. Shear transmission of overlapped surface, compatibility of stress and deformation is ensured by structural and construction measures.

(10) Embedment depth of retaining structure, anti-sliding, anti-overturning, and overall stability of wall, as well as anti-swelling and anti-piping stability of base soil mass in front of wall must be calculated. Verification on bearing capacity of subsoil, subsoil deformation, and stability shall also be conducted for soft ground. If necessary, reasonable measures shall be taken for ground improvement.

6.5.2.2 Engineering Overview of Working Shaft

During construction, working shaft acts as launching shaft for shield and shall satisfy launching requirements of shield; during operation, it shall satisfy the need of vehicle operation and shall reserve sufficient space for installation of fans, pipelines inlaying and emergency escape.

(1) Working shaft on the west bank

Design chainage of working shaft on west bank is CK2+530~CK2+550. In accordance with central distance of shield line, sufficient space shall be reserved on both sides for inner structure of shield advance. The perimeter dimension of working shaft in plan is 40m×20m with site elevation of +4.5m and excavation pit depth of 21.910m.

(2) Working shaft on the east bank

Design chainage of working shaft on east bank is CK5+000~CK5+020. In accordance with central distance of shield line, sufficient space shall be reserved on both sides for inner structure of shield advance. The perimeter dimension of working shaft in plan is 40m×20m with site elevation of +2.65m and excavation pit depth of 22.897m.

6.5.2.3 Design for Retaining Structure of Working Shaft

Excavation pits of working shaft on the west and east banks are 21.910m and 22.897m deep, respectively and shall be categorized as deep excavation pit works. Diaphragm wall is suggested as the design scheme.

It is suggested that the diaphragm wall shall be 1200mm thick and will form overlapped wall with lining wall and act as a part of permanent structure. The diaphragm wall for the west and east working shafts is 44m and 45m long respectively. In addition, in light of the 100 year design flood level of +6.8m (MSL elevation), the flood control elevation is designed as +7.3m. As the elevation of the east working shaft is only around +2.65m, far lower than the design flood control level, a temporary cofferdam is required to be built during construction, its elevation will be +7.3m to ensure site safety during construction.

Figure 6.5.2.3-1 Photo of Working Shaft of Shield-driven Tunnel

6.5.2.4 Main Structure Scheme of Working Shaft

The eastern and western working shafts of this project adopt same structural type, i.e. underground rectangular space box-shape structure, with plane size of 40×20m. During operation stage the embedment depth of bottom plate of eastern and western working shafts is 21.710m and 22.697m respectively.

The retaining wall of main structure of working shaft adopts overlapped wall composed of 1200mm thick diaphragm wall and 1000m thick lining wall. The bottom plate uses 1600mm thick reinforced concrete. As the working shaft has large plane size, with the length and width proportion of nearly 2: 1, and the opening of two shield holes of working shaft wall is very large, one 1000mm-thick mid-partition wall is set vertically along the working shaft, which separates the working shaft into two nearly square spaces, thereby reducing horizontal span of side wall of working shaft and significantly improving space stress performance of working shaft.

Taking western working shaft as an example, the main structure scheme of working shaft is shown below:

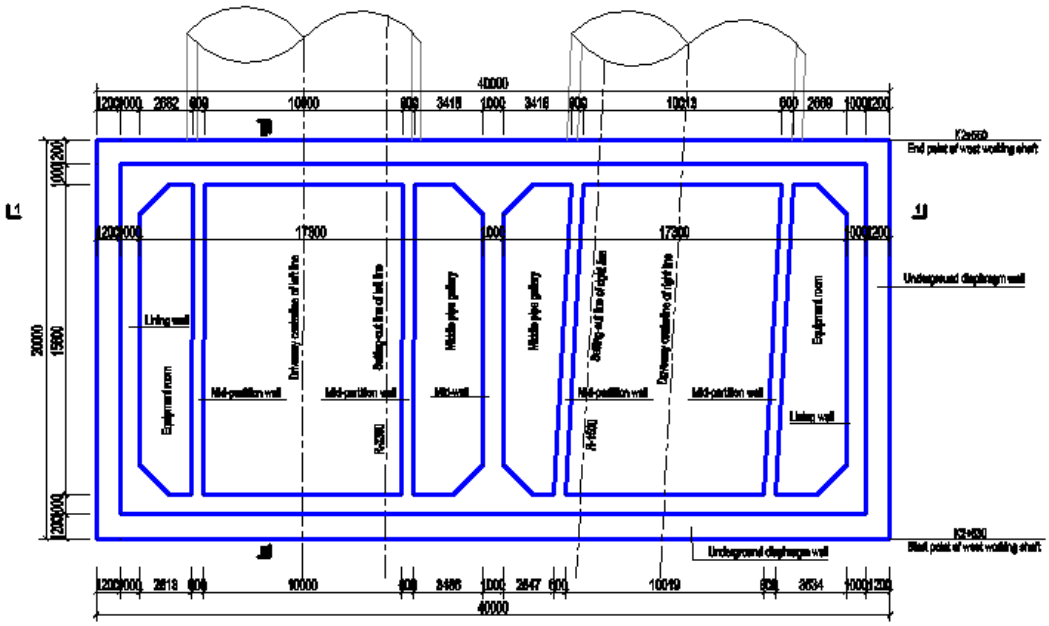


Figure 6.5.2.4-1 Plan of Shield-driven Working Shaft

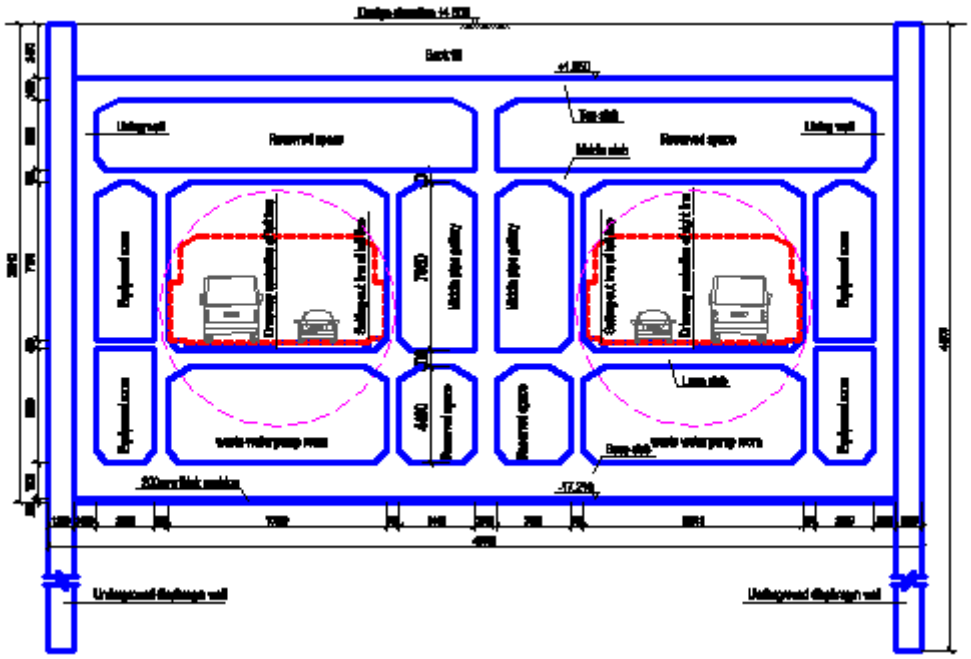


Figure 6.5.2.4-2 Cross Section of Shield-driven Working shaft

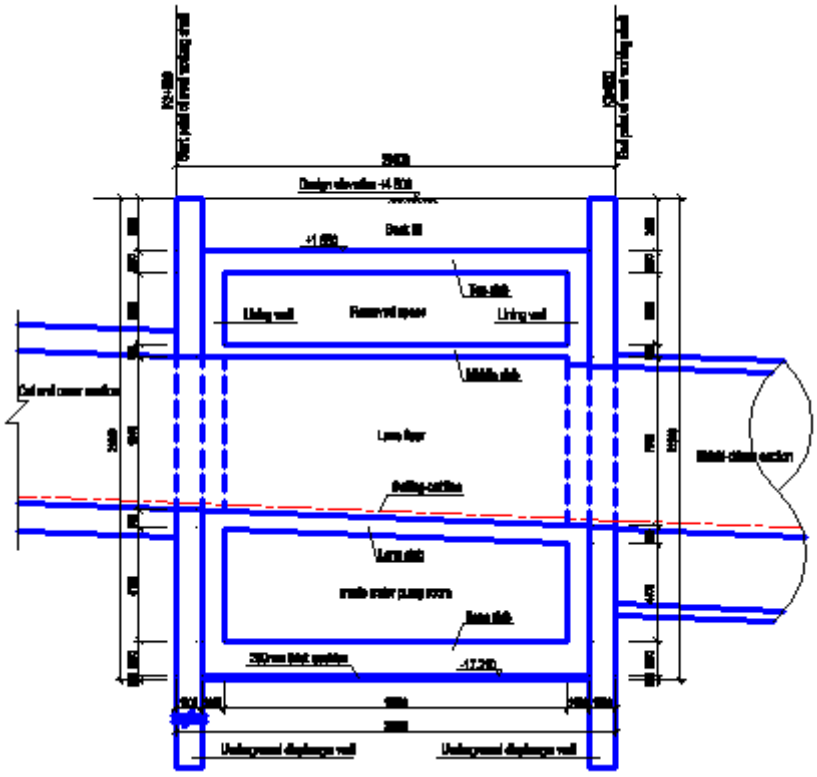


Figure 6.5.2.4-3 Longitudinal Section of Shield-driven Working shaft

6.5.3 Structural Design of Bank Side Sections

6.5.3.1 Design Principle

(1) Structural design shall be safe, reliable, economic and reasonable with advanced technology and convenient construction.

(2) Structural design shall satisfy the contents in such aspects as construction, application, planning, fire prevention, earthquake resistance, water prevention and ventilation, and comply with the principles of rigid, durable, stress resistant, safe and convenient construction and rational cost.

(3) Proper structural type, embedment depth and construction scheme shall be selected according to the environmental condition, engineering technical requirements, engineering geology and hydrogeology of the project, and upon comprehensive comparison in aspects of technology, economy, construction period, construction mode, environmental impact and operation effect.

(4) Structural design shall be based on survey data; reasonable design method by sections shall be selected according to the different structural types, construction methods, application conditions and load characteristics in different sections of the project.

(5) Structure net height shall satisfy the requirements of construction, ventilation, equipment, application, and construction process and consider the influence of construction error, structural deformation and settlement in late period.

(6) Unfavourable impact to the environment during and after the construction shall be considered.

(7) Structure is Class I in safety grade and design working life is 100 years. Calculation shall be carried out to structure according to the construction period and operation period respectively.

(8) Chittagong is located in Seismic Zone II with the horizontal seismic zone coefficient of 0.15. Structural seismic design shall be conducted based thereon.

(9) The allowable value of crack width shall be determined according to structural type, application requirements and local environmental condition.

(10) Structural anti-floating shall be designed according to full water buoyancy at the highest underground water level.

(11) Vertical bearing capacity, foundation deformation and stability shall be calculated for soft foundation of structural base. Retaining wall also serves as part side wall of main structure and shares force with inner lining. It shall be reliably connected with bottom plate and top plate of main structure to ensure structural force and deformation harmony.

(12) As for retaining structure design, the safety grade of excavation pit works shall be determined according to the surrounding environmental condition, excavation depth of excavation pit and retaining structure shall be designed according to the corresponding requirements.

(13) Design safety coefficient of excavation pit works shall be obtained by multiplying basic safety coefficient and additional safety coefficient. Reasonable supporting system for different sections shall be adopted according to the safety grade requirements of excavation pit in different engineering sections. Strength, deformation and stability calculation shall be conducted for supporting structure design according to the most critical load combination of construction section.

(14) Embedment depth of retaining wall of excavation pit shall meet the calculation requirements of anti-overturning stability of retaining wall, overall

stability, and anti-swelling and anti-piping stability of soil at the bottom of the excavation pit.

6.5.3.2 Engineering Overview of Bank Side Sections

(1) West bank side section

West bank side section is from K2+170 to K2+530 with the overall length of 360m. The open-cut section is straight, from K2+170 to K2+350, with the overall length of 180m and vertical slope of -4%; the cut-cover section is straight to curve section, from K2+350 to K2+530, with the overall length of 180m and vertical slope of -4%.

(2) East bank side section

East bank side section is from K5+020 to K5+570 with the overall length of 550m. The open-cut section is straight, from K5+400 to K5+570, with the overall length of 170m and vertical slope of 4%; the cut-cover section is straight to curve section, from K5+020 to K5+570, with the overall length of 380m and vertical slope of 4% in maximum.

6.5.3.3 Structural Design of Retaining Structure in Embankment

(1) Comparison of retaining structure in bank side section

There are many retaining types for excavation pits, for instance, steel sheet pile, SMW pile, bored pile and diaphragm wall.

A comparison of different retaining systems is listed at **Table 6.5.3.3-1**.

Retaining structure	Advantages	Disadvantages	Remarks
Steel sheet pile	1. High strength and light structure; 2. Excellent waterproofing performance; 3. Recyclable; 4. Simple and convenient construction;	1. Relatively high cost 2. High requirements for equipment	Excavation pit is about 5m deep
850mm SMW	1. Retaining Structure can retain soil and resist seepage, with flexible arrangement, convenient construction and excellent anti-seepage effect; 2. Profile steel is recyclable, thus cost is lower;	1. Small structural rigidity and large deformation; purlin system is required and support needs to be changed during construction of inner structure; 2. High cost of permanent structure; 3. When structural anti-floating can not be satisfied, additional anti-floating measures have to be used, which will	Excavation pit is about 10m deep

		increase construction cost;	
800mm bored cast-in-place pile	1. Use mechanical construction, can adapt to different soil layers, construction progress is under control; 2. Low cost of retaining structure; 3.Cast-in-place pile can be used in anti-floating;	1. Purlin system is required and support needs to be changed during construction of inner structure; 2. Waterstop curtain has to be made separately thus requiring more equipment;	Excavation pit is about 13m deep
800~1200mm thick diaphragm wall	1. Good integrity, strong stability and small deformation; 2. Can be used as permanent structure;	1. Relatively high cost	Excavation pit is about 15m~22m deep

Table 6.5.3.3-1 Comparison of Enclosure Scheme of Excavation pit

(2) Retaining Structure design

Four retaining ways including Larssen IV sheet pile, SMW pile construction method, bored pile and diaphragm wall are used for retaining the embankment. To ensure flood control safety on the east bank during construction and operation period, a permanent cofferdam is established for open-cut section on the east bank and a temporary cofferdam for cut & cover section, both of them have the same elevations as that of the east working shaft, i.e. +7.3mMSL. Some base plates of structure in east bank open-cut section has an elevation higher than that of the original ground, for which subgrade backfill shall be conducted first before the main structure construction commences. See Error! Reference source not found. for list of type of retaining structure for excavation pit at bank side sections.

Beginning and Ending Chainage	Length/m	Depth/m	Retaining Type
K2+170～K2+260	90	1.568～4.551	Larssen IV steel sheet pile
K2+260～K2+320	60	4.551～7.050	SMW pile (profile steel inserted every other one) (φ850@600mm)
K2+320～K2+410	90	7.150～10.650	SMW pile (profile steel inserted everyone) (φ850@600mm)
K2+410～K2+470	60	10.750～13.250	φ800@950mm bored pile
K2+470～K2+530	60	13.250～15.650	800mm thick diaphragm wall
K5+020～K5+080	60	15.626～17.048	Temporary cofferdam+1000mm thick diaphragm wall
K5+080～K5+170	90	12.978～15.626	Temporary cofferdam +800mm thick diaphragm wall
K5+170～K5+230	60	10.494～12.978	Temporary cofferdam

			+φ800@950mm bored pile
K5+230～K5+260	30	9.268～10.494	Temporary cofferdam + SMW pile (profile steel inserted everyone) (φ850@600mm)
K5+260～K5+320	60	6.852～9.268	Permanent cofferdam + SMW pile (profile steel inserted everyone) (φ850@600mm)
K5+320～K5+380	60	4.298～6.852	Permanent cofferdam + SMW pile (profile steel inserted every other one) (φ850@600mm)
K5+380～K5+460	80	0.966～4.298	Permanent cofferdam + Larssen IV steel sheet pile
K5+460～K5+570	110	-	Permanent cofferdam +step-slope excavation

Table 6.5.3.3-2 Type of Retaining Structure for Excavation pit at Bank Side Sections

6.5.3.4 Main Structure Scheme of Bank Side Section

(1) Open-cut section structure

U-shape groove structure is adopted for main structure in open-cut section. Greening median strip is set between the right and left lanes.

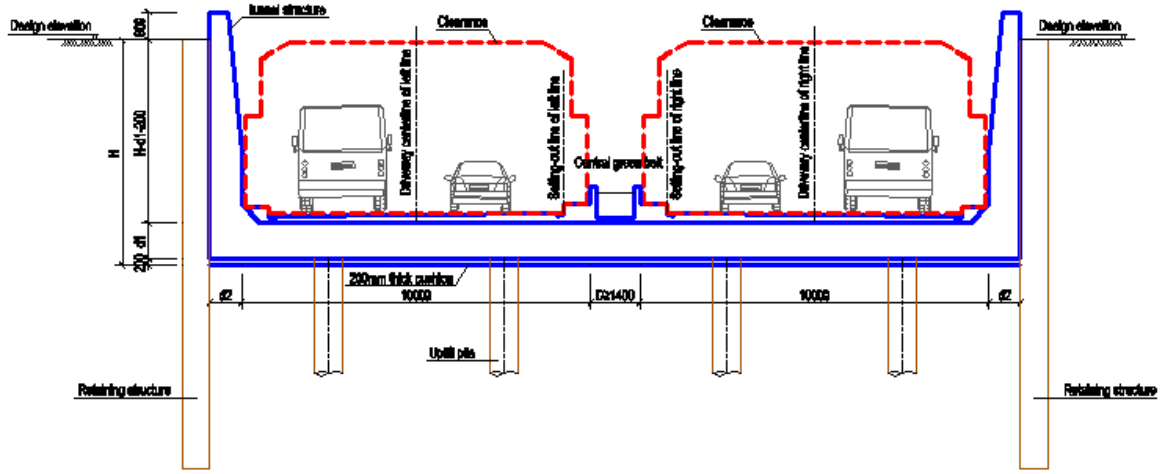


Figure 6.5.3.4-1 Cross Section of Open-cut Section

(2) Cut and cover section structure

Rectangular framework structure is adopted for main structure in cut & cover section and middle pipe gallery is built to act as cable equipment and inspection passage. When D＜3200 mm, i.e., the distance between the left and right setting-out lines is smaller than 4800 mm, the middle pipe gallery will have one reinforced concrete mid-wall and one masonry partition wall as its two sides, in which the partition wall doesn't act as bearing structure, when D≥3200mm, i.e.,

the distance between the left and right setting-out lines is larger than 4800 mm, the middle pipe gallery will have two reinforced concrete mid-walls as its two sides. Among which D=Distance between left and right setting-out lines-(700+100)×2.

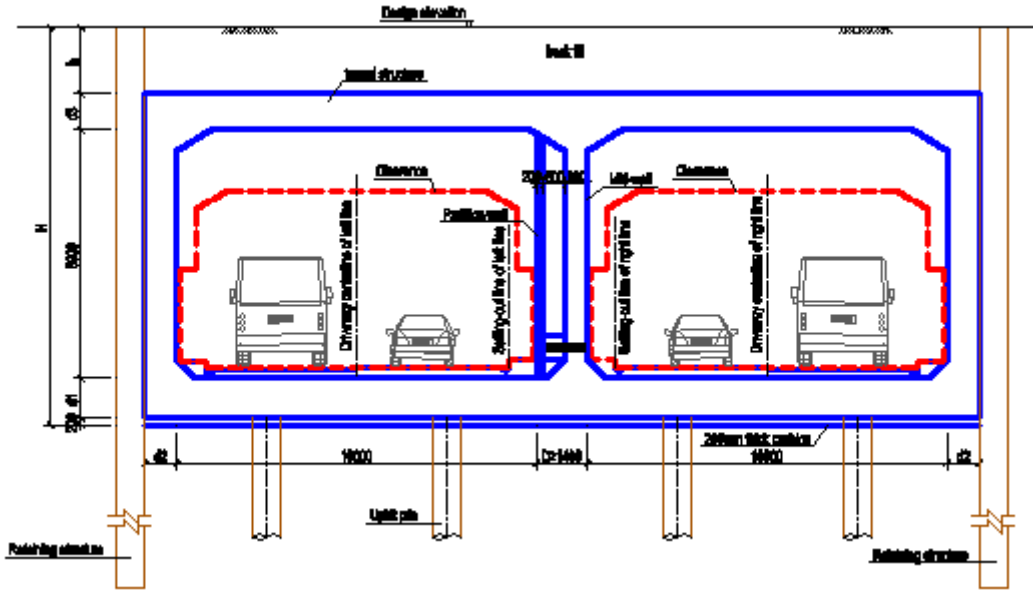


Figure 6.5.3.4-2 Cross Section of Cut & Cover Section (without middle pipe gallery)

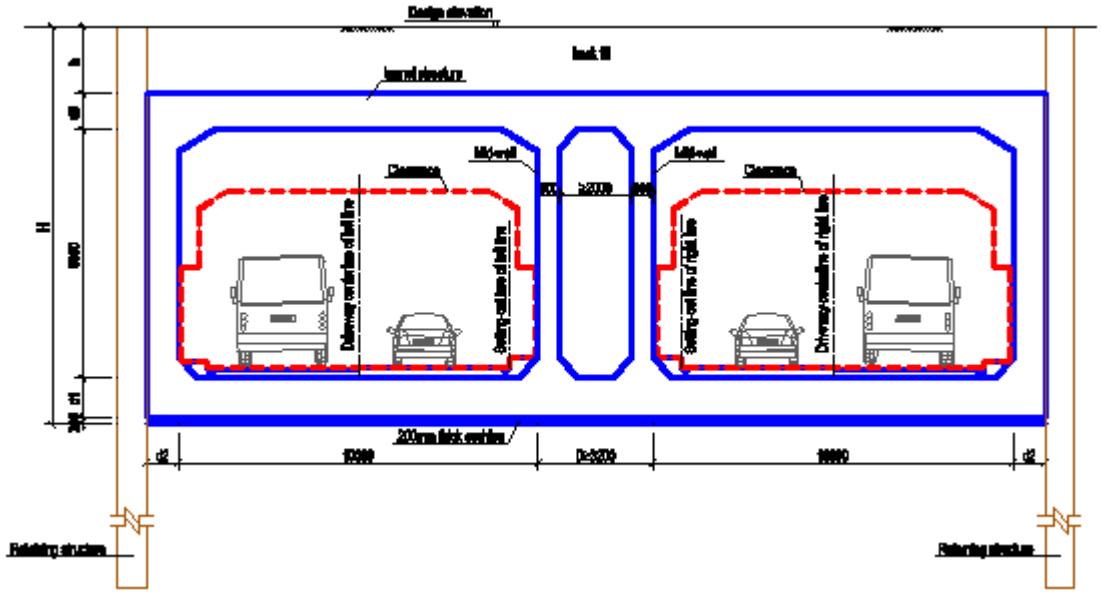


Figure 6.5.3.4-3 Cross Section of Cut & Cover Section (with middle pipe gallery)

(3) Structural anti-floating design

To ensure anti-floating stability of the project, dewatering measures by dewatering well shall be operated during the construction period. To ensure anti-floating stability in operation period, anti-uplift pile is adopted as structural anti-floating measure for the bottom plate of open-cut section.

(4) Engineering material

a. Cement: Grade 42.5 cement

b. Concrete:

Concrete Grade	Applied locations
C50 waterproofing concrete and anti-seepage grade P8/P6	Bottom slab, top slab, side wall and diaphragm wall
C45 concrete	Mid-partition wall
C45 concrete	Anti-uplift pile
C35 concrete	Retaining pile and king post
C20 early strength concrete	Bottom slab binding layer

Table 6.5.3.4-1 Major Material List

c. Steel:

Steel: HPB235 HRB335

Steel: Q235B

I-shaped steel: I32a

H-shaped profile steel: H700×300×13×24mm

Steel strut: φ609×16mm

6.5.4 Waterproofing Design of Tunnel

It is extremely essential to provide good waterproofing on the tunnel.

6.5.4.1 Design Rules

(1) Based on principles of "prevention first and comprehensive control and harness";

(2) Take self-waterproofing of structure as basis and joint waterproofing as key point;

(3) Ensure that waterproof performance can meet the requirements at high water pressure and maximum joint splaying;

(4) Strengthen waterproofing at the special locations such as the connections between the tunnel and the working shaft, anti-uplift pile and base slab, etc.

(5) Determine seepage resistance grade in accordance with the structure embedment depth H: when H<10m, the design seepage resistance grade is P6; when 10m<H<20m, the design seepage resistance grade is P8; when 20m<H<30m, the design seepage resistance grade is P10; when H>30m, the design seepage resistance grade is P12.

(6) The service life of the waterproof sealing material shall be 100 years (pass the heat ageing test of rubber materials and verified by Arrhenius equation).

6.5.4.2 Structure Waterproofing Design

Segment structure in shield-driven section, working shaft and main structure of bank side section shall all adopt waterproofing concrete structure, and concrete

anti-seepage grade shall be determined according to structure embedment depth H.

Structure	Segment structure of shield-driven section	Working shaft structure	Bank side section structure
Minimum embedment depth	18.95	21.910	1.220
Maximum embedment depth	53.45	22.897	17.048
Anti-seepage grade	P10/P12	P10	P6/P8

Table 6.5.4.2-1 Anti-seepage grade of tunnel structure concrete

6.5.4.3 Joint Waterproofing Design of Concrete Segment

From the perspective of function, late addressing and long-term structural safety of the project, single-layer waterproofing scheme is recommended.

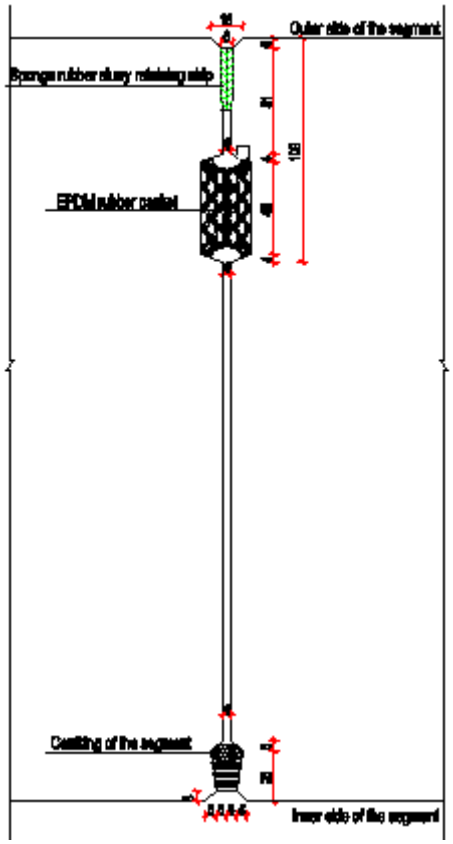


Figure 6.5.4.3-1 Single-layer waterproofing

6.5.4.4 Sealing and Waterproofing at the Launching and Receiving Shafts of the Shield

(1) Waterproofing and sealing at the launching shaft of the shield-driven machine

For this project, the launching shaft of the shield-driven machine will use double hinge-type compression seal plate structure for sealing.

The seal structure at the launching shaft is shown as belowError! Reference source not found..

Figure 6.5.4.4-1 Seal Device at Launching Shaft of Shield-driven Machine

(2) Waterproofing and sealing at the receiving shaft of the shield-driven machine

Normally, there are two approaches for receiving a large-diameter shield-driven machine, viz. underwater receiving by filling the receiving shaft with water, and providing clamp-type curtain rubber board.

The contractor may select the approach to be used.

6.5.4.5 Waterproofing Design for Working Shaft and Bank Side Sections

(1) Non-joint waterproofing

When the retaining structure is not diaphragm wall, the outer side of main structure will be fully packed with single-surface self-adhesive waterproofing coiled material for water resistance; when the retaining structure is diaphragm wall, no waterproofing coiled material is set between lining wall and diaphragm wall.

(2) Waterproofing for construction joints

There are mainly two measures for the longitudinal construction joints on the structure: (i) provide steel sheet water stop in the longitudinal construction joints; (ii) apply adhesive on the interface between the old and fresh concrete, thus to increase adhesion and reduce cracking on the structure.

(3) Waterproofing for deformation joints

For the deformation joints, three courses of waterproofing will be made: (i) external waterproofing, namely, to provide waterproof strip outside the side wall and base slab, and pave waterproof material on the top plate face; (ii) intermediate waterproofing, to be made with embedded rubber water stop; (iii) internal reserved caulking groove, to be pointed with sealant. In order to reduce differential settlement between the deformation joints, the base slab is provided

with tongue and groove coupling, and other components with reinforcement shear rods to increase shear resistance at the deformation joints.

6.5.5 Tunnel Durability Design

6.5.5.1 Design Principle

(1) Durability design of structural material, construction process and construction quality control and management shall be fully considered and properly controlled by reasonable design and corresponding construction measures so as to ensure the integral durability performance of concrete structure, to extend deterioration initial period or reduce deterioration speed in development period as much as possible and to satisfy the requirements of structure design service life.

(2) Tunnel shall be inspected, maintained and repaired and material degradation and structural faults shall be found as early as possible. Timely and corresponding maintenance measures shall be taken to minimize structure deterioration speed, to delay structure failure time and to reduce the risks of structure durability failure.

(3) Durability design shall be made to the structure of the project according to ocean chloride environment.

6.5.5.2 Structural Durability Design in Shield-driven Section

(1) Structural environmental analysis

For the exterior and interior of the shield-driven section, highly durable standard segment structure shall be used due to the difficulty in maintenance.

(2) Technical requirements for structural concrete

Concrete with large content of mineral admixtures shall be used for segment structure and lane slab for shield-driven section. Silica, 3%-5% weight of gel material shall be added in the mineral admixture. See the table below for other technical requirements of structural concrete in shield-driven section.

Components	Segment structure	Lane slab	Foundation and wall	Inverted arch backfilling
Concrete anti-seepage grade	P10/P12	-	-	-
Concrete grade	C60	C45	C35	C25
Water to binder ratio	≤0.36	≤0.4	≤0.5	≤0.6
Thickness of concrete protective layer /mm	60	55	40	-
Maximum crack width control	0.15	0.2	0.3	-
Chloride diffusion coefficient at the age of 28d D_{RCE}（$10^{-12}m^2/s$）	≤4	≤7	-	-

Maximum chloridion contents	0.1%	0.1%	0.2%	-

Table 6.5.5.2-1 Major Technical Index of Structural Concrete in Shield-driven Section

6.5.5.3 Structural Durability Design of Working Shaft and Bank Side Section

(1) Structural environmental analysis

Highly durable standard segment structure shall be used for the working shaft and the surroundings of structure in cut & cover section,. High durability standard should be adopted for the main structure in open-cut section. The durability design of tension pile can be slightly lower than that of main structure.

As retaining and supporting structure are temporary, it is not necessary to consider durability. However, durability design shall be made to the retaining structure when it serves as part of permanent structure. Therefore, durability design shall be made to diaphragm wall by referring to the side wall.

(2) Technical requirements for structural concrete

Concrete with large content of mineral admixtures shall be used for main structure of working shaft and bank side sections. Silica, 3%-5% weight of gel material shall be added in the mineral admixture. See the table below for other technical requirements of structural concrete in working shaft and bank side sections.

Components	Bottom plate, top plate, side wall and diaphragm wall	Mid-partition wall	Uplift pile	Temporary retaining, supporting structure and column pile
Concrete anti-seepage grade	P6/P8/P10	-	-	-
Concrete grade	C50	C45	C45	C35
Water to binder ratio	≤0.36	≤0.4	≤0.4	≤0.5
Concrete protective layer thickness /mm	60	55	50	-
Maximum crack width control	0.15	0.2	0.2	-
Chloride diffusion coefficient at the age of 28d D_{RCE} ($10^{-12}m^2/s$)	≤4	≤7	≤7	-
Maximum chloridion contents	0.1%	0.1%	0.1%	-

Table 6.5.5.3-1 Main Technical Index of Structural Concrete of Working Shaft and Bank Side Section

6.5.5.4 Special Measures for Dealing with Adverse Environment

Protective measures to be taken under adverse environment:

(1) During construction, control jacking force generated by the shield jack to avoid crack expansion on the ring face.

(2) Provide anti-corrosion treatment on the surfaces of embedded steel items.

(3) It is necessary to apply epoxy mortar on the inner surfaces of the concrete inside the pump house in order to enable them resistant to the oil substances dripped from vehicles or corrosive liquor carried by a special-purpose vehicle flowing into the pump house when a sudden accident occurred.

(4) In view of corrosion to the bolts on the lining segments by the waste gas inside the tunnel, it is necessary to seal all the hand holes and caulking grooves on the lining along the entire tunnel. This measure can not only improve corrosion resistance of the bolts, but also enhance exhaust efficiency.

(5) The internal surface of the ventilating shaft and the surrounding tunnel area will have more waste gas and faster air speed. If water leakage exists in the joints, the relative humidity of the air around this area will become larger, which will speed up carbonization of the concrete. To slow down corrosion caused by carbonization on the concrete lining segments, silane coating is necessary to be applied on the inner surfaces of the 100 lining rings at the side of the exhaust duct, which is effective in protection of concrete for no less than 10 years,

(6) Condensate from waste gas (CO_2, NO_x, SO_2 etc) exhausted by vehicles will accumulate on the inner surfaces of the lining segments. Chlorine ion may also build up in the inside joints and cracks on the lining segments, all of these built-up substances will accelerate corrosion to the lining segments. Therefore, it is necessary to clean the inner surfaces of the lining segments prior to equipment installation, decoration and when replacing the vault finish layer.

6.5.5.5 Quality Inspection and Long-run Monitoring on Concrete Durability

(1) Take samples from the field concrete, prepare test specimens and determine dispersion coefficient of chlorine ion.

(2) Measure the compactness of the concrete cover by rebound tester or by testing compression strength of the concrete on the component surface. When necessary, core will be taken directly from the component and tested, thus to determine compactness of the concrete cover indirectly.

(3) Determine the actual thickness of the concrete cover through non-destructive testing using reinforcement concrete cover thickness gauge.

(4) Monitor the healthy conditions of the concrete structure on a long-run basis, to ensure that the concrete structure meets the durability requirements.

6.5.5.6 Waterproofing Material Durability of Shield Tunnel

(1) Durability control of flexible rubber sealing gasket

Polyurethane swelling sealing strip is set outside the flexible rubber sealing gasket as first defensive line, strengthening the durability of flexible rubber sealing gasket which acts as main waterproofing line of joints.

(2) Rate of change of physical performance of caulking sealant after being soaked in acid and alkaline solution (polyurethane type and TR type) is controlled to satisfy durability requirements.

6.5.5.7 Durability Design of Metal Components

(1) Anti-corrosion design of connecting bolt

a. Hand hole of the whole tunnel segment is sealed by low expanding cement and cast-in-place concrete in tunnel through blocking. Such action can reduce ventilation resistance and extend service life of bolts.

b. Zinc chromate coating layer + closed corrosion resistance method is used for bolt surface with overall thickness of coating layer of 6~8μm.

(2) Corrosion resistance of steel segment

To improve durability of steel segment, epoxy zinc rich primer and ultra-thick plasma bituminous epoxy paint are used for corrosion resistance treatment and the overall thickness of dry film for two paints is 290μm.

(3) Corrosion resistance of metal embedded parts of shield tunnel and rectangular tunnel

Vinyl ester glass flake is used for coating and the overall thickness of primer and finish dry film is 350μm. The durability of such coating and effective protection time for concrete shall be no shorter than two decades.

6.5.6 Seismic Design of Tunnel

6.5.6.1 Seismic Environment

From the seismic zoning map, it can be seen that Chittagong is not in the zone of the highest risk, it is in seismic zone II, which is of medium risk / hazard, with design horizontal seismic zone coefficient of 0.15. Seismic zoning in Bangladesh is shown in the map below:

Figure 6.5.6.1-1 Seismic Zoning in Bangladesh

6.5.6.2 Seismic Performance of Tunnel

The main factors influencing tunnel seismic performance can be generally summarized as seismic hazard, geologic conditions, and tunnel design and construction.

(1) Seismic hazard

In a broad sense, earthquake effects on underground tunnel structures can be grouped into two categories: ground shaking and ground failure. Based on tunnel performance records during past earthquakes, the damaging effects of ground failure on tunnels are significantly greater than the ground shaking effects.

(2) Geologic conditions

Apart from ground instability, there are other unfavourable geologic conditions that could lead to unsatisfactory seismic tunnel performance, such as soft soils, rocks with weak planes intersecting a tunnel and so on.

(3) Tunnel design and construction

To ensure a favourable seismic performance, tunnel design and construction should agree with these principles:

a. seismic loading should be explicitly considered in the tunnel structure calculation and design.

b. junctions between shield segments and junctions of tunnel with other structures should be design to adapt to the seismic shaking.

6.5.6.3 Seismic Measures

The following measures are considered for seismic design at the current stage:

(1) Liquid soil layer shall be avoided in planning tunnel lines. If it is unavoidable due to special reason, secondary grouting can be conducted to strengthen solidify liquid soil layer.

(2) Ring and longitudinal joints shall adopt bolt connection satisfying seismic structural requirements so as to maintain structural continuity.

(3) Enhance aseismic performance of the tunnel lining, increase seismic capacity reserve of the tunnel itself, maintain proper rigidity on the lining segments body and joints, take suitable waterproof measures, and make proper design under the condition of meeting the requirements of both economy and safety.

(4) Flexible sealing gasket is set in the longitudinal deformation joint to adapt to certain deformation of layer in earthquake.

(5) Deformation joint shall be set near working shaft and tunnel joints to adapt to the uneven settlement in proper volume. Large deformation ring is set where great changes occur to underlying layer to deal with large uneven settlement occurred to tunnel structure in earthquake.

6.5.7 Measures for Flooding, Global Warming and Extreme Climates

In recent years, offshore hydrological and climatic environment has been changed due to Green House Effect which mainly reflected in sea level rise. Living environment of human beings will be seriously threatened by the sea level rise. Scholars from all over the world did a large amount of statistical study on sea levels in the past as well as study on factors and mechanism of sea level rise. It was generally agreed that factors lead to change of sea level mainly include sea water temperature, salinity, water inland and geophysical change of the earth, etc., but there are still lots of disputes about degree of influence. According to statistical results, variation of sea level is between 2.5 and 3.84 mm/a in recent 10 years, but sea level rise showed a trend of acceleration. The ascent amplitudes of sea level of Northwest Pacific Ocean and East Indian Ocean are the largest, which is 10 times of global average level. The Bay of Bengal is at northeast of Indian Ocean, whose sea level will rise about 12cm during tunnel construction estimated

upon a change speed of 3cm/a. Crest elevation of cofferdam designed by the project is 7.3m, which is able to withstand typhoon and surge of 100-year return period with a sea level rise 50cm under extreme conditions.

Growth speed of sea level in future is uncertain. It is difficult to predict accurately the specific value of sea level rise during tunnel operation period. As sea level rise is a slow process, it is suggested that height of cofferdam shall be raised when sea level rises during tunnel operation period. Construction cost for cofferdam heightening is included in maintenance cost during operation period.

Sea level rise will result in increase of frequency and strength of tropical cyclone, which will lead to extreme climates such as typhoon and tsunami. The following measures can be adopted under extreme climates:

(1) Build permanent cofferdam at the tunnel portals. Elevation of cofferdam shall be designed according to the elevation of water table caused by typhoon and surge under return period of 100-year;

(2) Build a flood-prevent gate at tunnel portal. Close tunnel and stop traffic passing under condition of heavy rain and extreme climates;

(3) Setup reasonable pumping house for raining in the tunnel as per statistical results of local precipitation.

6.6 Traffic Engineering and Facilities along the Alignment

6.6.1 Tunnel Traffic Engineering

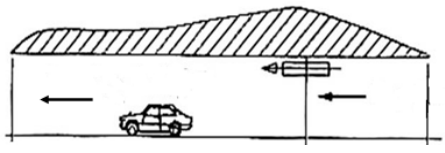
6.6.1.1 Tunnel Ventilation

- Ventilation hygiene standard

Traffic condition	CO concentration (ppm)	Smoke concentration (m^{-1})
Normal	70	0.005
Traffic jam	70	0.007

Table 6.6.1.1-1 Ventilation Hygiene Standard Recommended by PIARC (in 2010)

- Ventilation scheme



Given consideration to tunnel section, engineering cost, portal environmental protection and operation management, by combining the characteristics of the project, **full jet flow longitudinal ventilation way** is used in Karnaphuli tunnel. This kind of ventilation can use the whole tunnel space as ventilating duct. It is also unnecessary to set a special ventilating duct. Induced draft can be formed for ventilation by using jet fan thrust at the top of tunnel, which can effectively utilize piston air when vehicles drive and it can reduce equipment costs and operation power costs. Such system is an energy-saving ventilation system.

- Ventilation scale

Tunnel name	Period	Congested (L≤1 km)	Slow idling	Normal operation working condition		Fire disaster	Gas exchange	Number of fans
		≤10km/h	20km/h	30km/h	40~80km/h			
Karnaphuli river tunnel	Left tunnel in short term (set)	8	18	8	-	16	10	18
	Left tunnel in long term (set)	12	24	8	-	16	10	24
	Right tunnel in short term (set)	8	18	8	-	16	10	18
	Right tunnel in long term (set)	12	26	8	-	16	10	26

Table 6.6.1.1-2 Tunnel Fan Configuration

6.6.1.2 Tunnel Lighting

High pressure sodium lamp characterized by excellent cold rendering, high lighting effect, long service life and strong penetrating power to smoke is recommended for tunnel lighting.

Tunnel emergency lighting time shall be no shorter than 2hours.

Approach lighting facilities are set for the roads outside the tunnel entrance and exit.

Tunnel lighting adopts 4-level control, i.e. rainy day, cloudy day, evening and night.

Power failure occurs frequently in Bangladesh. The duration of power failure is between 3 and 6 hours each day based on preliminary survey results. Diesel generator shall be used for power supply to maintain lighting when there is a failure of electricity supply. If high voltage sodium lamp is used for lighting of the project, initial cost for equipment is low, but the cost at operation stage is high. LED lamps for lighting is also suggested as alternative scheme. Compared with high voltage sodium lamp, power consumption of LED lamp is only 60% of that of high voltage sodium lamp under same illumination. It will effectively save cost of supplying and distributing power cable, and cost during operation stage. However, initial cost of LED lamp is higher than that of high voltage sodium lamp. During detailed design and construction stage, lighting scheme shall be selected considering the initial equipment cost and operation cost.

6.6.1.3 Tunnel Power Supply and Distribution

Tunnel electricity load can be divided into three levels according to its importance. Reliability and continuous power supply shall be ensured for Level-1 load. Power supply reliability shall be guaranteed for Level-2 load and continuous power supply shall be ensured. Two power loops are required for power supply. The rest of the tunnel belongs to Level-3 load with one feasible loop power supply.

As for the most important Level-1 load within the tunnel (such as escape indication, fire disaster alarm and central control, etc.), emergency power shall be set in addition to two independent power supplies;

Tunnel power supply shall be from the reliable power supply network from the regional power department and the recommended system voltage is 11KV.

6.6.1.4 Tunnel Monitoring

Tunnel traffic grade is determined according to tunnel length and sectional traffic volume of the recommended alignnment. Corresponding monitoring, ventilation, lighting control, fire disaster alarm and central control management facilities are set according to traffic grade and current traffic monitoring system in the region. Tunnel central control chamber of the project is set at the east portal.

6.6.1.5 Tunnel Water Supply and Drainage and Fire Fighting

(1) Water drainage system

Water drainage pump room is set in the lowest point of tunnel and pump room collecting basin is set below the plank of roadway within the escape way. Low-flow and high-lift effective water drainage pump with small volume is used for the submersible water drainage pump established inside. .

Underground rainwater pump room is set near tunnel portal to prevent rainwater from entering the tunnel. Water level will be monitored automatically rainwater and waste water pumps and relevant info will be delivered to the control centre.

(2) Fire fighting

Fire fighting extinguishing facilities shall be set for tunnel fire fighting in addition to fire disaster automatic monitoring alarming and refuge equipment.

Besides conventional fire fighting system, advanced foam-spray interlinking automatic extinguishing system is used for the narrow and dense space inside the tunnel in view of the characteristics of large smoke and rapid temperature rise when fire disaster happens.

One manual butterfly valve shall be set for each fire fighting pipe and drainage pipe in the tunnel utility corridor, for the convenience of inspection.

6.6.1.6 Tunnel Disaster Prevention and Rescue

1) Fire disaster prevention and rescue

Complete safety alarming and rescue equipment shall be set and effective emergency scheme associated with monitoring and ventilation shall be formulated to minimize disasters so as to reduce chain reactions and accident seriousness.

Tunnel disaster prevention design shall adopt the policy of "prevention first in conjunction with fire fighting". Design shall be focused on the actual condition of disaster. Fire shall be extinguished once discovered in tunnel to avoid serious disaster. As for the preliminary fire disaster happened in the tunnel, the principle of "self-rescue first and first-aid supplementation" shall be adopted to ensure that tunnel users can take advantage of fire fighting alarming and extinguishing equipment within the tunnel conveniently. Once large fire disasters happen, personnel within tunnel should be provided with basic escape means.

Tunnel must be closed upon the occurrence of accidents and different control strategies are adopted according to the actual situation. Motorized lane and sidewalk connecting the right and left truck channels can be used as the refuge channel for vehicles and personnel. Corresponding lighting and fire-proof door facilities are also set within it as the emergency channel for evacuating stream of people and traffic flow when fire disasters happen.

2) Flooding prevention and rescue

The tunnel is located under Karnaphuli river and waterproofing capacity of the structure is of great importance in design.

As for flooding prevention of traffic project, rainwater pump room shall be set near tunnel portal. The drainage capacity is designed according to the rainstorm for every 50 years so as to effectively prevent water outside the tunnel from entering tunnel through the portal. Waste water pump room is set in the lowest point of river to eliminate fire fighting water and possibly penetrated water within the tunnel. In addition, anti-flooding gate is set in the open-cut and cut & cover section (combined with air defence door) to prevent river water from entering the downtown or external flood from entering tunnel after disaster accident happens.

6.6.2 Toll Station and Traffic Facilities along the Alignment

6.6.2.1 Setting of Management Maintenance Organization

One highly effective management organization shall be established. In particular, as the charging management involves timely recovery of construction capital and debt-paying period, one functional department which can coordinate high-grade highway shall be available.

Two-level management system is recommended (relevant management organization of Chittagong Government management maintenance center of the project): the project is in unified charging management. The management station shall be set near the interflow interchange near the town, which cannot only facilitate business management entering in or exiting from highway but also help employees arrange their lives, and also shorten the distance with local tele-network and save length of communication cables. One management center is recommended.

One management station shall be set in the project and the maintenance station and the main toll station shall be combined.

6.6.2.2 Safety Facilities

- Traffic sign

Signs along the entire line are in English supplemented by local language if necessary.

- Marked line

To strengthen marked line legibility at the entrance and exit of interchange ramps and stand out road signal setting, road hubs are set within the range of zebra line of the entrance and exit every 10 meters.

- Guard rail

Wave from beam rail is set for the middle belt. Ramp middle belt shall be restrained by its width and combined wave from beam rail is also set.

- Sight guidance facility

Sight guidance facilities can be divided into three kinds:

The first one is to set reflector near middle belt and the side rails to guide vehicles with the spacing of 24cm. Interchange skylight ramp section shall be denser according to the radius of ramp.

The second one is to set diversion and interflow guidance. Diversion and interflow places shall be set for ramps near the entrance and exit of interchange so as to remind drivers to pay attention to vehicle diversion or interflow.

The third one is to set guidance arrow mark in small radius curve section, mainly at the outer side of interflow ramps so as to highlight line driving directions.

- Glare screen

Glare screen is set in the middle separation belt to avoid glare to vehicle lamps when driving at night. Anti-glare panel is mainly used for glare resistance and installed in the zoning rail.

6.6.2.3 Road Electrical & Mechanical Engineering System

Electrical & Mechanical engineering system mainly consists of main line monitoring, communication, toll and power lighting system and tunnel operation facilities.

Major targets: to monitor the implementation of the whole line timely; to establish toll system, communication system so as to secure a modern, high-standard and digital superhighway.

1) Monitoring system

Tunnel and inter changes shall be monitored in priority and the while the entire alignment shall be monitored; meanwhile, complete information feedback system shall be set in place.

(1) System

Monitoring branch is set for the project in management and maintenance center and video monitoring system is used for road section monitoring.

(2) Monitoring data transmission

All the field equipment adopts single mould optical transmitter and receiver to transfer information to the branch one by one.

(3) Monitoring video transmission

Video signal of all the closed-circuit TV is transferred to the branch directly after taking remote node access equipment with coding protocol of H.264.

2) Communication system

The project is set with special communication network to realize highly centralized modern management, to ensure superhighway and other operation requirements and to provide continuous reliable communication lines.

The project adopts SDH+ access network scheme. The access network system of the line consists of comprehensive business access network equipment. According to the management scheme of the project, communication branch of the project is set in management and maintenance center.

Composition of access network: built-in SDH STM-4 equipment is used as ring network for the transmission of access network.

Digital stored program control exchange of management and maintenance center is used in this section to distribute telephone and user's telephone adopts diphone multi-frequency key-pressing type.

12 Φ40/33 high-density polyethylene silicon barrel is used in the whole line as the principal tubing of the pipeline.

3) Toll system:

Open toll system for controlling entrance and exit of some sections can be used. Main toll station can be set in CK6+800 and vehicles commuting in urban areas can be charged so as to control main traffic volume and gains. No charge will be made for the roads on two bank sides.

According to the predicted traffic volume, six entrances and exits are set for the toll lanes of main toll station to satisfy traffic volume requirements in 2025. In addition, given consideration to the gradually increased traffic volume, it is predicted that the toll station scale will be unable to satisfy the service level in 2028. At that time, 4 artificial toll lanes will be reconstructed as 2 respective entrances and exits ETC lanes to relieve traffic pressure.

Toll system adopts semi-automatic toll way of identifying vehicle and charging by people, TV monitoring, computer management and detector checking.

Cost of land acquisition and labour cost is high. To save operation cost (reduce toll station scale and number of staff) and cost of land acquisition, ETC automatic toll lanes with 2 entrances and 2 exits are also suggested as alternative scheme. Therefore, toll station can be reduced to 4 entrances and 4 exits. However, construction cost at early stage will be increased and extra producing and advertising costs of ETC card should be paid.

4) Lighting system

Highway always adopts full lighting and power supply is introduced locally supplemented by special power line.

Cut-off lamps and high pressure sodium lamp light source are used for motorized vehicle lane with lamp power of 400W. Pavement design brightness is 1.5cd/m^2 and lamp installation height is 12m with installation spacing of 36m. Lamps are arranged in lane separator.

Cut-off/semi-cut-off lamps and high pressure sodium lamp light source are used for non-motorized vehicle lane and auxiliary lighting with lamp power of 150W. Pavement design brightness is 0.5cd/m^2 and lamp installation height is 8m with installation spacing of 24m. Lamps are arranged at the edge of subgrade.

30m high mast illumination is used in interflow area with lamp power of 12*1000W. Pavement design brightness is 1cd/m^2.

The general evenness of illumination design brightness is no smaller than 0.4, brightness vertical evenness is 0.7 and glare control index G is no smaller than 5.

5) Power supply system

One 11kV power system is introduced in service area (CK8+050), management and maintenance center (CK6+700) of the whole line and tunnel entrance and exit of Alignment C (CK2+150 and CK5+500), and central power supply is adopted. Power is connected to different transformer substations through high voltage cables.

Box-type transformer substation is set for every 2km, providing illumination of road lamp and high mast and monitoring equipment within the range.

6) Buildings

Design of supporting building facilities of the project includes building location, scale determination and design scheme. According to the operation and management condition and requirements along the line, one main toll station management center, one maintenance work zone and one tunnel maintenance center are provisionally determined in the project.

Facilities	Land area (hectares)	Building area (m^2)	Remarks
Main toll station management center	Co-establishment with main toll station square	1500	Six-in-six-out
Maintenance work area	Co-establishment with main toll station square	700	Maintenance material warehouse and offices of maintenance managers are considered, personnel logistics are not considered

Tunnel maintenance center	Co-establishment with the east tunnel portal	400	Distribution and monitoring function and rest room of monitoring personnel are considered, other personnel's logistics are not considered.

Table 6.6.2.3-1 Buildings

6.7 Additional Suggestions with Tunnel Construction Scheme

The tunnel construction scheme shall take the climate conditions of Chittagong into full consideration; make proper arrangement for construction procedures by overall planning and considerations.

A practical and workable plan for crossing Karnaphuli River embankment shall be prepared for tunnel construction.

6.8 Summary

(1) Dual two-lane tunnel design without non-motorized vehicle lane and sidewalk is recommended at the current stage.

(2) Cross section type of twin-tube dual two-lane is recommended at current stage.

(3) Through comprehensive comparison among the various tunnel construction methods suitable for this project, shield-driven method is recommended for tunnel construction.

(4) Design for major technical parameters of shield segment is made at the current stage. The segment for shield tunnel is 10.8m in diameter, 0.5m in thickness and 2m in ring width. Common segment with taperness of 36mm is adopted. The segment separation adopts the way of 5+2+1, i.e. total 8 pieces, including 5 standard pieces, 2 adjacent pieces and 1 capping piece. Both ring and longitudinal joints of segment adopt inclined bolt connections.

(5) Retaining Structure type for bank side sections and working shaft are compared and analysed at current stage; sheet pile, SMW pile construction method, bored cast-in-place pile and diaphragm wall are adopted respectively as retaining structure in accordance with different excavation depth.

(6) According to structure stress and concrete durability design requirements, preliminary design on material and size of main structure is made.

(7) Preliminary study on waterproofing structure of shield segments and bank side section structure is made at the current stage.

7. PRELIMINARY COST ESTIMATE

7.1 General

This estimation is prepared based on the approximate quantity by the preliminary tunnel design, referring to the projects already completed and those still under construction in the area where this project is located. The unit rate of each work item is obtained by analysing the costs of international technical expert and local labour, local materials, imported materials, and machinery. The preliminary cost estimation covers various work items, including road subgrade works, tunnel works, equipment purchasing and installation works, other cost of project construction, tunnel special cost, reserve funds, and loan interest during construction period, etc.

7.2 Unit Rates

7.2.1 Unit Rate of Materials

The material unit rates are obtained through market survey. The materials unavailable in Bangladesh adopt unit rates of imported materials.

7.2.2 Charges for Machinery Use

The operating cost of the construction contractor includes the following:

(1) Cost of fuel, oil, and lubricants;

(2) Salary of machine operators, which is calculated as 13.55×1.5=20.33 USD/man-day;

(3) Maintenance cost for machinery;

(4) Charges for unused machines.

7.2.3 Labour

Minimum wage standard set by Government of Bangladesh is considered in the labour rates. The labour consists of international technicians and local labour. The weighted calculation is as below:

(1) Unit rate of international technician

The unit rate of international technician = 238.10+3174.60/12+850 =1352.65 USD/month=65.98 USD/man-day.

(2) Unit rate of Bangladesh local labour

Unit rate per man-day of common labour is USD 5.00, and that of technical labour is USD 10.00. The proportion of common labour to technical labour is calculated as 6:4.

(3) Weighted average unit rate per man-day

The proportion of international technician to Bangladesh local labour is about 1:8 and the ratio of work efficiency is about 1:1.8.

65.98×1/9+(5×0.6+10×0.4) ×8/9=13.55 USD/man-day.

7.2.4 Purchasing Cost of Tunnel Equipment

The tunnel equipment is considered to import from foreign country. The cost consists of equipment cost and freight & miscellaneous charges (calculated as 5% of equipment cost).

7.2.5 Purchasing Cost of Office and House Furnishings

With reference to similar overseas underwater tunnelling projects, USD 2,778/km is adopted for calculation tentatively.

7.2.6 Taxes and Profit

Profit is calculated as sum of direct costs and indirect costs minus 10% of registration fee. Taxes are calculated as 11.7318% of sum of direct costs, indirect costs, and profit.

7.2.7 Requirements on Contractors

Well-equipped contractors with rich experience in international market should be selected to undertake tunnel construction.

7.3 Project Construction Cost

7.3.1 Costs of Construction of the Project

Costs of Construction of the Project for the three options have been calculated at the current prices. However, construction of the project is likely to commence in 2013.

- Consultancy fee of feasibility study is calculated as 1.5% of cost of construction and installation works.
- Technical design fee is calculated as 8% of cost of construction and installation works.
- Technical censor fee is calculated as 10% of technical design fee.
- Geological investigation and surveying fee is calculated as 4% of cost of construction and installation works.
- Site supervision fee is calculated as 2% of cost of construction and installation works.
- On-site technical service fee is calculated as 1.5% of cost of construction and installation works.

- Fees for three supplies (supply of water, electricity and road) and one levelling (levelled ground) and temporary project cost are calculated as 2.5% of cost of construction and installation works.
- Administrative fee is calculated as 1.5% of construction cost of Part I.
- Project insurance cost is calculated as 0.55% of construction cost of Part I.
- Land acquisition fee and resettlement compensation fee are listed as USD 47,639,300 based on the price obtained through field survey.
- Cost for tunnel and equipment maintenance is listed as USD 1,828,000. The charge of shield machine and accessories is listed as USD 34,217,400.

7.3.2 Project Investment Scheduling

The project is planned to complete in 48 months.

According to the estimation of project construction expenditures, the proportion of loan allocated to each year is as below: 20%, 30%, 30%, and 20% respectively from first year to the last year.

7.3.3 Loan Interest in Construction Period

Loan interest during construction period is considered as the rate of the bank loan. The credit limit is 70% of the total project cost excluding loan interest. The interest rate is 18%.

7.3.4 Reserved Fund

The reserve fund is calculated as 7% of sum of the costs of Part I, II and III (exclude the loan interest during construction period).

7.4 Maintenance Cost

The daily maintenance cost for traffic engineering (including tunnel electrical and mechanical equipment, road electrical and mechanical equipment, and traffic security facilities) is USD 1,800,000/year (price in July 2012), with inflation coefficient of 5%/year. Regular maintenance cost is USD 1,900,000 every five years (price in July 2012), with inflation coefficient of 5%/year. It is calculated from the first operation year.

7.5 Operation Cost

According to the price level in 2012, the total operation costs are estimated to be BDT 171,620,000 /year. Considering that the costs relating to salary, electric charges and diesel oil accounts for a large proportion of the total cost, the inflation coefficient is determined as 8% every year.

If energy-saving lamp in alternative scheme and scheme of ETC automatic lane is adopted as well as taking reducing service level of toll station into account, the operation cost can be reduced to 160,000,000 BDT per year.

If alternative schemes of energy-saving LED lamp and ETC automatic lane are adopted, and service level of toll station is reduced to a lower level, the operation cost can be reduced to 160,000,000 BDT per year.

7.6 Conclusions

Alignment C of this project has a total length of 9.092 km, with total project cost of USD 674.91 million and project cost per km of USD 74.23 million.

8. ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT PLAN

8.1 Scope

The key components of the study include: (i) review of all proposed alignments and selection of final alignment; (ii) assessing engineering, economic, social, and environmental aspects of the project; (iii) consultations with a wide range of stakeholders to ensure community participation; (iv) preparing a recommended alignment for Government approval and preliminary engineering design for the preferred alignment and project cost estimates; (v) assessing economic viability and compliance with safeguards; (vi) preparing the financing plan and assessing financial sustainability of the project; (vii) preparing the procurement plan and implementation arrangements (See Environmental Impact Assessment Report).

8.2 Methodology

The Consultant prepared this EIA as part of the Feasibility stage based on the detailed review of proposed final alignment, engineering works, field investigations, stakeholder consultation, primary and secondary data collection, screening of all baseline environmental parameters, environmental quality baseline monitoring, and review of other road/bridge project reports in Bangladesh. The EIA covers the general environmental profile of the Project area including physical, ecological, environmental, social, cultural and economic resources.

The collected data and information have been processed by identification, prediction, and evaluation of likely potential/significant impacts. The source and potential level of impact arising from the implementation of project have been determined by utilising the Matrix Method. Thereafter, possible mitigation measures on negative impacts and enhancing measures for positive impacts have been identified. An Environmental Management Plan has been developed based on the findings of impact appraisal comprising the key elements embodied in this EIA study.

8.3 Consultation during Feasibility Study

In the initial stage of the project, a series of consultation meetings，focus group discussion public consultation were held.

The key findings of the meetings are as follows:

- Impacts (including from induced development) on coastal landscapes, habitats as well as protected areas and related mitigation, minimization, avoidance and compensation measures to be addressed comprehensively.
- The project should contribute into comprehensive improvement of the BBA/MOC organizational structure, mechanisms, systems, plans and capacity for managing environmental, social, health and safety issues, including enforcement mechanisms and monitoring systems. Related

institutional strengthening should be provided with adequate budget and human resources.

- Adequate set of environmental and related management plans should be developed or clearly outlined, whenever impossible to elaborate details. All these plans should be clearly bound into construction and supervision contracts.
- Spoil disposal are the major environmental issues related to the tunnel construction projects. These aspects should be described in details and related detailed quantities and costs (including site-specific details) included in the project design and reflected in the EMP structure and implementation budget as well. Comprehensive mitigation and restoration measures to be specified.
- EIA should be comprehensive but also very site specific in assessing and mitigating impacts. Engineers should provide details of proposed alignments so that environmental baseline, impacts and mitigations can be analyzed in sufficient spatial detail. Environmentally sensitive locations, geo-hazards and crossings to be addressed in detail.
- Climate change/sea level rise impact on the project should be considered in the design;

Consultants responded that updated EIA is being prepared at the detail design stage and will be disclosed later. The documents will address all the raised issues.

8.4 Environmental Impact Assessment

8.4.1 Approach

The Consultant prepared this EIA as part of the Feasibility stage on the basis of detailed review of proposed final alignment, engineering works, field investigations, stakeholder consultation, primary and secondary data collection, screening of all baseline environmental parameters, environmental quality baseline monitoring, and review of other road/bridge project reports in Bangladesh. The EIA covers the general environmental profile of the Project area including physical, ecological, environmental, social, cultural and economic resources.

8.4.1.1 Pre-construction Phase

8.4.1.1.1 Social Impacts

Land Acquisition

A total of 28.96 hectare lands will be required to implement the project of which 5.02 ha will be acquired for Patenga end and remaining 23.94 ha will be for KAFCO end. Among them about 9.20 ha is kash land, 3.47 ha is road, 10.91 ha fallow land and 5.37 ha is private land. Though land ownership has been determined based on field survey and consultations but actual owners of the acquired land would be selected based on record of right by the Deputy Commissioner.

It is mentionable that the tunnel alignment will run through middle of the KAFCO and CUFL establishments. The alignment will not touch the main structure of these heavy industries but boundary wall and some small structure of KAFCO may be affected by the project interventions. There is conveyor belt of the CUFL on the alignment which needs to cross by any reasonable means. The project has designed this portion to cross the said conveyor belt through constructing flyover. Land acquisition has been proposed for this portion and accordingly budgetary allocation for land acquisition has been kept.

Project Affected People

Total 2487 affected population, 53.56% and 46.44% of the population are male and female respectively. There are 2389 affected people (96.06%) at KAFCO End (East) area and 98 (3.94%) at Patenga end.

Loss of Structures

It is found that total 423 nos. primary structures (houses, shops, kitchen, etc.) covering 1,57,649 square feet are affected under the entire Karnaphuli Tunnel Project. The highest number and floor areas of primary structures are 200 nos. *katcha* (made of CI sheet roof with wooden of bamboo fence) covering 55,807 square feet floor areas are affected under this project while the lowest number and floor areas of primary structures are 13 nos. pucca (concrete roof with brick wall) covering 40,971 square feet floor areas.

It is found that only 22 structure (5352 sft) are affected at Patenga end (west) whereas 414 (152297 sft) are found affected at KAFCO end (east). The highest number of affected primary structures at Patenga is 18 CI sheet roofed houses covering 4237 square feet. On the contrary, in the KAFCO End (East) area the highest number of the affected primary structures are 199 (*katcha)* covering 55207 square feet.

As the survey result revealed, a total of 52 secondary structures are affected in both ends of the tunnel alignment by the project interventions. Out of the total 52, only 8 secondary structures are affected at Patenga end (boundary wall and bill board) and 44 at KAFCO end including latrine, boundary wall, tube well, pipe, etc.

Loss of Common Property Resource

There are 15 common property resources (CPRs) affected by project, these include Mosque-2, Madrasah-2, Primary School-1, Eidgah-1, Passenger shed-1, Mazar/prayer room-3, Club-1, Ticket counter-1, Union Parishad office-1, graveyard-1 and cremation ground-1 are being affected by the project interventions.

8.4.1.1.2 Environmental Impacts

Loss of Trees

The tunnel alignment and other components will require cutting of about 780 different sizes and species of trees.

Risk due to Earthquake

The project area falls in zone 2, i.e. moderate seismic zones (Z=0.15) as per the Bangladesh National Building Code (BNBC). Necessary seismic factors

suggested by BNBC shall be incorporated suitably while designing the structures to safeguard against earthquake risks.

8.4.1.2 Construction Phase

Generally, construction impacts are expected to last for a relatively short time period and are expected to cease soon after the completion of construction. Construction impacts are considered to be minimal as all the construction works will be carried out within the site boundary on the acquired land and will be controlled via the mitigation measures defined in this EIA. If Contractor does not comply with the environmental specifications, serious long term environmental problems could emerge.

8.4.1.2.1 Resource and Waste

Materials used during construction mainly comprise ready-mixed concrete, prefabricated concrete tunnel segments, steel, aggregates, asphalt, and specialist materials (grouting, sealants, etc) and this these will be procured by the construction contractor and at this stage their sources are not known. Given the size of the construction sector in Bangladesh it is not expected that any specific facilities for local supply of materials will need to be developed outside the construction site and all will be supplied from the existing marketplace. During feasibility study, it was decided that the contractor will use spoil materials as filling which is generated by Open cut method. No major impact is expected to be associated with the disruption of the earth surface.

Various types of vehicles and machinery typically used during tunnel construction will be needed. These will all be sourced locally from existing suppliers. During the detailed design and procurement stage, the EPC contractor will be responsible for identifying sources for all materials and equipment and will be required to consider environmental impacts in selecting materials to be used on the Project. This will include using less harmful materials where possible, considering the carbon footprint of alternative materials and considering the impacts of extraction, processing and transport.

8.4.1.2.2 Geology, Soils

Geological Resources

Excavation works have the potential to affect geological sites and other features of importance to science and to cause land instability. As large sediment loosening is expected for Karnaphuli tunnel, the preliminary support must be provided that it is active over the whole excavated sediment surface and develops an adhesion grip with the sediment. The nature of preliminary support and the time of its installation should be fixed on the basis of the measured deformations of the sediment/rock mass. The works are not expected to cause any risk of land instability.

Soils

The contractors will be required to adopt good construction site practice for protection of soils and to follow IFC EHS Guidelines on Construction Materials Extraction and the IFC EHS Guidelines for Toll Roads. Specific measures for

protection of soils, prevention of erosion and appropriate storage and handling of hazardous materials are described in the EMP.

8.4.1.2.3 Surface and Ground Water Pollution

There is potential for both surface and ground water pollution directly and indirectly by the construction of tunnel. Stripping of road surfaces, stockpiling of earth materials, tunnel construction are all activities that can result in the release of unwanted earth materials into water bodies. This can be an irreversible impact, if not mitigated properly.

The main potential sources of impact from construction activities will be discharge of effluent from the TBM slurry treatment plant, discharges from dewatering of deep excavations, discharge of site run-off potentially contaminated with silt and hazardous materials, sewage disposal, wheel washing, accidental releases from work sites, and release of specialist chemicals used in tunnelling and grouting.

The risk of significant impacts will be reduced through adoption of a range of controls set out in the EMP.

During geological investigation it was reported that the maximum depth to dry season groundwater table is 16-17 m that is 9-10 m during monsoon. In the surrounding aquifers the water heads are above the mean sea level and very close to the surface with significant water table fluctuation. As groundwater levels are higher in most places than the base level of the proposed tunnel, excavations will require a dewatering system. Pumped wells can be used to temporarily lower the groundwater table outside the excavation support during construction. To minimize any lowering of the water table immediately outside the excavation, water pumped from the excavation can be used to recharge the water bearing strata of the groundwater system by using injection wells.

Groundwater has a particular influence on the design of all constructions in rock mass/sediment. In soils, particularly in cohesive types, the level of groundwater has an effect on the internal resistances, load carrying capacity, compression capacity, etc. The seepage pressures in rock mass and sediment as well as the static pressure on the lining are relieved through drainage. This needs to be considered during engineering design of tunnel.

8.4.1.2.4 Air Quality

The main sources of air emissions from construction works on the Project will be:

- dust emitted from excavation, earth moving, loading, handling and transportation of spoil;
- emissions of combustion gases from construction machinery and the vehicles

The spatial impact on air quality during construction is limited to the immediate vicinity of the work area. Increased dust and particulate is expected during dry months and windy days. Dust from aggregate production and construction traffic, emission from any bituminous plants and heavy diesel equipment will affect air quality during the construction phase. Minor impacts due to generation of fugitive

dust from earth-workings, air pollution due to exhaust gases from vehicular movement and traffic congestion will be managed by periodic watering of the construction material stockpile and working area and through controlled vehicle movement during the peak hours of local traffics. Air quality problem will be for a short period and minor impact is anticipated.

8.4.1.2.5 Noise and Vibration

During construction, the potential sources of noise are due to operation of construction related vehicular traffic, earth moving equipment, heavy machinery, and pile driving activities can generate high noise and vibration levels. Noise and vibration will have impact on people, fauna, live stock and natural environment.

Acoustic enclosures around the pile drivers will reduce the noise levels by 60 decibels and are strongly recommended. Regular maintenance of construction equipment and vehicles in accordance with manufacturers' maintenance procedures will greatly reduce the noise levels. Contractors are recommended to monitor the noise levels regularly at the construction sites and take necessary measures to comply with the national standards. High efficiency mufflers are to be fitted to the noise generating equipment. The construction related activities will be restricted between 0600 to 2100 hours within 150m of settlements and 500m from sensitive receptors (hospitals and schools etc).

Vibration annoyance and damage from construction work is most typically associated with percussive piling. Piling in the vicinity of sensitive premises will be carried out using vibration reduced techniques (bored piling or casings driven by torque and hydraulic pressure). Other sources of vibration could include operation of heavy equipment or vehicles. Associated vibration levels are low and will be short-lived but may be perceptible at receptors close to the construction activity.

The EPC contractor will be required to monitor vibration in sensitive buildings above the tunnel (hospitals, school, historic buildings etc.) to ensure the international requirements regarding vibration are met and if the standards are exceeded measures will be taken to reduce vibration. Relevant locations will be identified by the contractor and discussions held with the relevant parties to ensure construction is managed to avoid adverse effects on use of sensitive equipment.

8.4.1.2.6 Construction Camp

Contractors will recruit construction workers locally where possible, and should not discriminate in the employment of women. Priority will be given to employ people who facing loss of wage and/or other income. However, some of the workforce (especially the skilled) is expected to be recruited from outstation areas and hence temporary accommodation shall be provided at adjacent areas. Campsites for construction workers are the important locations that have significant impacts such as health and safety hazards on local resources and infrastructures of nearby communities.

The potential implications associated with housing of immigrant workforce include generation of solid waste, adverse water quality impacts arising from discharge of partially treated sewage and refuse, public health impacts through the

possible introduction of diseases not prevalent in the surrounding areas and promotion of disease vector habitats within the temporary housing areas, social-cultural conflicts arising from religious, cultural and behavioural discords between immigrants and local residents, and promotion of un-aesthetic practices. Such impacts, if they materialize, will generally be short term and tolerable. However, long-term adverse impacts on individuals and communities as a whole cannot be discounted. Hence, specific safeguards are required to be taken to quell potential adverse environmental, public health and socio-cultural impacts.

It is strongly recommended that the contractor should hire local workers as many as available. Contractor has to prepare a detailed layout plan of the construction camp with the design of sewerage facilities and locations of relative locations for all temporary buildings and facilities that are to be constructed together with the location of site roads, fuel storage areas (for use in power supply generators), solid waste management and dumping locations and drainage facilities. It should be submitted to BBA for approval prior to the development of the construction camps. Local authorities responsible for health, religious and security shall be duly informed on the set up of temporary accommodation facilities so as to maintain effective surveillance over public health, social and security matters.

The camps should have adequate housing for all workers, safe and reliable water supply, fuel supply, waste disposal facilities, hygienic sanitary facilities and sewerage system, treatment facilities for sewerage of toilet and domestic wastes, storm water drainage facilities, adequate health care facilities, and in-house community/common entertainment facilities.

The Contractor shall conduct ongoing training programs to all construction workers on basic sanitation and health care issues and safety matters, and on the specific hazards of their work and HIV awareness programming, including STI (sexually transmitted infections) and HIV information, education and communication. Complement educational interventions with easy access to condoms at campsites as well as voluntary counselling and testing.

The contractor shall restore all the construction camps to original condition after completion of civil works.

8.4.1.2.7 Community Impacts

Construction worksites may place stresses on resources and infrastructure of nearby communities. This may lead to conflict between residents and workers. To prevent such problems, the contractor will provide temporary worksite facilities such as health care and eating space. In addition, a grievance redress mechanism will be established that allows local people to raise grievances arising from the construction process. Labour intensive construction and the use of local labour during the construction will increase benefits to the local community and resolve such conflicts. Contractors will communicate to the public through community consultation and public announcements regarding the scope and schedule of construction, as well as certain construction activities causing disruptions or access restrictions.

The Project will have significant impacts on both urban economics and rural poverty in the project area. The tunnel construction will create lots of job opportunities to the local community. It is expected that about 1800 people will be employed during construction. The construction of the tunnel constitutes the long-

term improvement of economic conditions in the Chittagong due to better traffic access. The greatest beneficiaries from a monetary standpoint will be the current road users, who will experience greater efficiency, higher safety, time and operational cost reduction, and less wear and damage to their vehicles. From a numerical standpoint, the largest group of beneficiaries will be all kind of people around Chittagong city and the periphery by getting rid of traffic congestion and huge traffic flow. Second group will the local people, who will have improved access to markets and cheaper transport costs for their commercial produce.

Local residents will also be benefitted from expanded opportunities for seasonal employment elsewhere to earn supplemental incomes. Rural villages will also have improved delivery of health, education, and other social services by virtue of all weather feeder and rural road connections to the approach roads. With the year-round access to new markets provided by the Project, the village level enterprises will also prosper, promoting local economic growth.

8.4.1.2.8 Health, Safety and Hygiene

Construction sites are likely to have health and safety impacts. There will be a potential for diseases to be transmitted, exacerbated by inadequate health and safety practices. There will be an increased risk of work crews spreading socially transmitted diseases such as HIV/AIDS. Mitigation measures include: (i) provision of adequate health care facilities within construction sites; (ii) an health and safety manager, appointed by the contractor for each site, and first aid facilities will be made readily available; (iii) training of all construction workers in basic sanitation and health care issues (e.g., how to avoid transmission of sexually transmitted diseases such as HIV/AIDS), general health and safety matters, and on the specific hazards of their work; (iv) personal protection equipment for workers, such as safety boots, helmets, gloves, protective clothing, goggles, and ear protection; (v) clean drinking water and safe sanitation for all workers; (vi) adequate protection to the general public, including safety barriers and marking of hazardous areas; (vii) safe access across the construction site to people whose settlements and access are temporarily severed by road construction; (viii) adequate drainage throughout the work sites to ensure that disease vectors such as stagnant water bodies and puddles do not form; and (ix) Septic tank and garbage box will be set up in construction site, which will be periodically cleared by the contractors to prevent outbreak of diseases. Where feasible the contractor will arrange the temporary integration of waste collection from work sites into existing waste collection systems and disposal facilities of nearby communities.

Intensive movement of heavy trucks is required to deliver required amount of materials to the needed sites within the construction corridor. The impacts anticipated in this regards are noise and vibration, traffic congestion, air pollution, dust and risks associated with refuelling and vehicle cleaning. The construction sites impose certain safety risks for the population and, therefore, compliance with safety rules is important. The contractor is responsible for ensuring that all construction vehicles observe speed limits on the construction sites and on public roads and to provide adequate signage, barriers, and flag persons for traffic control.

8.4.1.2.9 Flora and Fauna

Terrestrial

The alignment will not pass through forest area. During the field survey the local people reported no endangered flora species along the proposed route and right of way.

Aquatic

The siting of the proposed construction of tunnel and alignment of approach roads will not isolate/disconnect any feeding/breeding ground of fish and will not prevent or inhibit migration of fish. Further, construction of tunnel will not encroach wetlands which may alter the ecology of wetlands/swamplands. So, no impact is anticipated.

Historical and Cultural Monuments

No historical or cultural monuments will be affected/lost due to the tunnel implementation.

8.4.1.3 Operation Phase

8.4.1.3.1 Operational Materials and Waste

Quantities of materials used and waste generated during operation of the project are expected to be small. Occasional hazardous wastes may arise from maintenance operations, clearance of drainage sumps and clean up of accidental spills. All waste (hazardous and non-hazardous) will be managed in accordance with legal requirements. No significant impact is predicted to arise from resource use or waste disposal during operation.

8.4.1.3.2 Impacts on Soil

During operation soils may become contaminated with road run-off pollutants including PAH (Polycyclic Aromatic Hydrocarbons) and metals. These compounds arise from spills, corrosion, wear of tyres and brake linings, and general wear of the car. The Project is designed with a closed drainage system in which road run-off will be collected at the lowest points in underpasses and the tunnel, and discharged in compliance with the local legislation. Normal road run-off should not therefore have any significant impact on soils.

Operation of a closed drainage system and establishment of emergency response plans to be implemented in the event of spills, fire etc should prevent significant impacts on soils during operation.

8.4.1.3.3 Impacts on Water Quality

The principal risk to the water quality during operation will be from discharge of contaminated road drainage to Karnaphuli River, groundwater or the sea. Road drainage can contain oily residues, particles from tyre and brake abrasion, particles from vehicle emissions and cleaning materials used during maintenance (e.g. during washing of the tunnel). More significant discharges may result from accidental spills of fuel or hazardous loads carried by vehicles.

A dedicated system will collect all road and tunnel drainage at sumps located at the low points along the route. The consultant recommended a review of the plans

to consider how the systems will integrate with the proposed Detailed Area Plan of Chittagong Development Authority. This study will be undertaken during detailed design to ensure an appropriate drainage arrangement is provided.

8.4.1.3.4 Impacts on Air Quality

Airborne emissions are generated by combustion of fuel in vehicle engines. The main source of emissions during operation will be from fuel combustion in vehicles approaching and passing through the tunnel. Emissions from vehicles in the tunnel will be collected by the ventilation system and emitted as point sources via the ventilation shafts at each end[6].

Development of the tunnel will also cause changes in the flows of traffic on other roads connecting to the approach roads and elsewhere around the city, with increases in flows on some and decreases on others. These changes will lead to increases and decreases in air pollution around these roads.

In order to predict the impact on the project on ambient air quality, air dispersion modeling will be carried out with project and without project scenarios during detailed design.

The impact generated by the emissions from the ventilation shafts is limited. The contribution of tunnel emissions to the ambient concentrations is unlikely to cause relevant standards to be exceeded beyond 25 m from the centre of each shaft. Within this area, people are not expected to be continuously present and adverse impacts on health are not therefore predicted. If, however, monitoring indicates that standards are being exceeded, the operating authority will look to increasing the ventilation rate from the shafts to improve dispersion and to planting around the shafts to prevent public access to affected areas.

8.4.1.3.5 Impacts on Noise Quality

Increase in noise level is anticipated due to increase in traffic movement. Proper traffic management and legal measures can easily control the unwanted increase in the noise level. Avenue plantations would dampen traffic-related noise. Intermix of vegetation consisting of local shrubs and trees will be raised along the tunnel alignment.

During detailed design, further studies will be carried out to confirm predicted noise levels, and mitigation measures will be developed as needed to address the significant noise impacts.

8.4.1.3.6 Impacts on Ecological Environment

No impact on floral resources is anticipated during operational stage of the project. During operation of the project, the water quality could be affected by accidents near river involving vehicles carrying mineral or hazardous substances and clogging of drainage system by grass, shrubs, and earth block due to storm water flow. A spill contingency plan will be prepared by the BBA.

[6] There will also be a small amount of emissions released at the tunnel entrances but this will be much smaller and has not been separately assessed.

8.4.1.3.7 Tunnel Ventilation

A transverse or semi-transverse system for ventilation is normally recommended when the length of bi-directional traffic tunnel exceeds 500m. However longitudinal ventilation system is more economical and safer according to the risk analysis of tunnel. Therefore, the longitudinal ventilation system is decided to be used for the tunnel ventilation.

The list below should be considered in design, construction and operation of the ventilation system:

- To control pollutants emitted by vehicles on the road under normal and peak traffic flow
- To control pollutants emitted by vehicles on the road where traffic is stopped due to any incidents such as to an accident
- To control heat and smoke in the event of fire

8.4.1.3.8 Tunnel Illumination

For the safety of the traffic, tunnel illumination (lighting) is designed and installed along the tunnel side walls at about 10 m interval. Transitional illuminations at both tunnel portals are designed too. Illumination is generally required for the tunnels longer than 50 m.

8.4.1.3.9 Emergency Facilities

For traffic safety, emergency facilities are planned in accordance with the length and gradient of the tunnel and volume of traffic.

8.4.1.3.10 Social Impacts

Impact on Socio-Economic

It is anticipated that the socio-economic impact will be positive for the local population. Regional economics is expected to improve due to improved access and increased transport efficiency. The local population will share this improvement and their income should rise as a result of improved transport efficiency. The effect of the multilane tunnel project in the long term on poverty reduction in the area is expected to be significantly positive.

Impact on Land-use

During operation of the tunnel, the impact on land is indirect. The project is expected to increase the economic activity, cause changes in the land use pattern, intensity of agricultural cultivation and population density.

Health and Safety

No negative impact is expected on health and sanitation after the construction. On the other hand, due to better access, health and sanitation situation of the area is expected to improve.

8.4.2 Findings from Environmental Impact Assessment

8.4.2.1 Construction Materials

The construction of the project will require large quantities of construction materials of various types and quantities. Local sources will be used as much as possible

8.4.2.2 Spoil Re-use and Disposal

Quantities of spoil generated in each part of the Project are identified in **Table 8.4.2.2-1**.

West Bank（m^3）			Remarks
Subgrade Soil Filling	103528	Spoil	Fill with Soil from West Bank Open Cut Disposal
Tunnel Open Cut Disposal	83813.4	Disposal	
Total：	19714.6	Spoil	
East Bank（m^3）			
Subgrade Soil Filling	429005	Spoil	
Tunnel Open Cut Disposal	136333.8	Disposal	
Cofferdam	369919.5	Spoil	Fill with Soil from East Bank Open Cut Disposal
	153555.1	Borrow Stone	
	101475.2	Basal Dredging (Disposal)	
Total：	662590.7	Spoil	
	153555.1	Borrow Stone	
	101475.2	Basal Dredging (Disposal)	Can be used for farmland fertilizer
	Shield-driven Section（m^3）		
Shield-driven cut	276948	Shield-driven slag (disposal)	Basically mud slurry,built mud & water Separation station for handling
Connection Channel	1108.8	Disposal	

Table 8.4.2.2-1 Quantities of Spoil

Source: Technical information from ARUP-CCCC JV, April 2012

8.4.2.3 Proposed Schedule for Implementation

The proposed project is scheduled to commence from 2013 and forecast to take 4 years for completion.

8.4.3 Impacts and Mitigations

8.4.3.1 Project and Area of Influence

In EIA a Project should be defined so as to include all those actions and activities which are a necessary part of the development, including all related and ancillary facilities without which the project cannot proceed, and also any other developments or activities which follow as a necessary consequence of the project.

The Multilane Tunnel Project under Karnaphuli River has been defined to include:

- The tunnel itself and the construction of the approach roads to the tunnel;
- Construction of flyover on CUFL conveyor towards Chaturi Chowmohoni;
- The Toll Plaza
- The Operational Building
- The tunnel ventilation shafts
- All sites and activities involved in the construction of the works;
- The traffic that will use the tunnel and the approach roads;
- Activities involved in long term operation and maintenance of the Project

The assessment also takes account of the influence of the Project on the Patenga and KAFCO area including its effect on traffic flows elsewhere on the road network and on patterns of future land use and development. Impacts have been assessed for all phases of the Project from initial site preparation and advance works, through construction, to operation of the tunnel. Decommissioning of the Project is not assessed as the tunnel is envisaged to remain in place and in operation for the foreseeable future.

Impacts have been assessed throughout the Area of Influence of the Project. This varies depending on the type of impact being considered, but in each case it is defined to include all that area within which it is considered that significant impacts could occur. This takes into account:

- the physical extent of the proposed works, defined by the limits of land to be acquired or used temporarily or permanently for the construction and operation of the Project;
- the nature of the baseline environment, the source of impact and the manner in which the impact is likely to be propagated beyond the Project boundary.

8.5 Environmental Mitigation Plan

8.5.1 Objective

The plan consists of mitigation, monitoring and institutional measures to be taken during implementation and operation to eliminate adverse environmental impacts, offset them, or reduce them to acceptable levels. The plan also includes the actions needed to implement these measures.

Details of all measures planned to avoid, reduce or compensate for adverse environmental and social impacts and to provide benefits where possible are set out in the Environmental and Social Management Plan (ESMP).

The ESMP is structured to identify:

- the required action;
- the reasons for its adoption and the desired outcome (e.g. achievement of a required environmental quality standard, protection or satisfactory reinstatement of a feature, disposal of waste in accordance with a defined approach);
- the basis for the action (e.g. legislation, guidance or Project ESIA commitment);
- responsibility for implementation and resources required (including detailed work procedures and financial resources);
- the timing of the action and any deadline for completion
- indicators of successful implementation;
- how success will be monitored or audited and any requirements for reporting;
- any additional information, including contingency arrangements in event of non-compliance

8.5.2 Proposed Environmental Management Measures

The ESMP addresses the full life-cycle of the Project from detailed design through to operation for the period of the BOT Contract[7]. The following summarizes the potential impacts which are to be controlled, the mitigation measures which are to be recommended and indicated time frame for implementation and responsibility for ensuring the management plans are efficiently implemented. This ESMP is outlining a preliminary; detail ESMP should be prepared during detail design stage.

A. <u>Pre-Construction Phase</u>

1. Environmental Impact/Issue: Land and Property Acquisition

[7] Closure and decommissioning are not considered as the tunnel is envisaged to remain in operation for the foreseeable future

Mitigation Measures: The acquisition of land and private properties has been carried out in accordance with the RAP and entitlement Matrix for the project. It shall be ensured that Resettlement & Rehabilitation activities be reasonably completed before the construction activity starts. All grievances of the PAPs will be reasonably redressed, in accordance with the RAP implementation mechanism suggested for the project.

Time Frame: Before construction activity starts

Responsibility: Implementation - Deputy Commissioner (DC), Implementing agency/INGO

Supervision - Safeguard Division, BBA

2a. Environmental Impact/Issue: Loss of Trees

Mitigation Measures: Necessary compensation has been paid directly by BBA to PAPs. Valuation of trees have fixed up as per market survey

Time Frame: Before construction activity starts

Responsibility: Implementation - Deputy Commissioner (DC), Implementing agency/INGO

Supervision - Safeguard Division, BBA

2b. Environmental Impact/Issue: Loss of Trees

Mitigation Measures: Identified trees will be removed from the site before the commencement of construction with prior approval of BBA.

Time Frame: After getting compensation amount

Responsibility: Implementation - INGO

Supervision - BBA

2c. Environmental Impact/Issue: Loss of Trees

Mitigation Measures: BBA will replant the uprooted trees.

Time Frame: After construction

Responsibility: Implementation - NGO

Supervision - BBA

3. Environmental Impact/Issue: Income disruption

Mitigation Measures: Compensation for structures, livelihood restoration grant, training for vulnerable people, plots in resettlement sites

Time Frame: During construction

Responsibility: Implementation - INGO

Supervision - BBA

B. Construction Phase

1. Environmental Impact/Issue: Construction Waste and Resources

Mitigation Measures: The Project shall seek to minimise the generation of spoil, re-use excavated soils in the Project area as far as possible and find alternative beneficial uses of surplus spoil where practicable so as to minimise the requirement for off-site disposal

Use spoil materials as filling which is generated by Open cut method

Surplus excavation material shall be made available to third parties for reuse on local development projects if it cannot be utilised on the Project site.

All surplus spoil and construction materials shall be disposed of at suitably designated disposal sites

Time Frame: During construction

Responsibility: Implementation - EPC

Supervision - BBA

2. Environmental Impact/Issue: Soils

Mitigation Measures: Topsoil, overburden, and low-quality materials shall be properly removed, stockpiled near the site, and preserved for rehabilitation. Newly exposed soil surfaces shall be protected against rainfall erosion in periods of heavy rain

Fuels, oils and chemicals shall be stored on an impervious base protected by a bund, and drip trays shall be used for fuelling mobile equipment. Any spillages from handling with fuel and liquids shall be immediately contained on site and the contaminated soil removed from the site for suitable treatment and disposal.

Procedures shall be set up for identifying and dealing with contaminated materials when encountered during construction, including treatment and disposal of contaminated soils. Contaminated material shall be remediated or

disposed of in an appropriately designated disposal site.

Time Frame: During construction

Responsibility: Implementation - EPC

Supervision - BBA

3. Environmental Impact/Issue: Water Pollution

Mitigation Measures: Run-off from construction sites and drainage from excavations including dewatering of deep excavations, shall be collected, treated and discharged in accordance with required permits.

All fuels, oils and chemicals shall be stored on an impervious base protected by a bund and drip trays shall be used for fuelling of mobile equipment.

Any spillages from handling with fuel and liquids shall be immediately contained on site and contaminated soil or water removed from the site for suitable treatment and disposal

Time Frame: During construction

Responsibility: Implementation - EPC

Supervision - BBA

4. Environmental Impact/Issue: Dust/air pollution

Mitigation Measures: Dust generating activities and stockpiles of dusty material shall be planned and sited to minimise the potential for dust generation taking into account prevailing wind directions and the locations of sensitive receptors. Dust generation shall be controlled by use of wind shields and water spraying as necessary in dry periods

Mixing equipment should be equipped with dust-removal device. Operators should pay attention to their health & safety.

Brick, concrete making, crushing plants should be located away from settlement as possible.

Time Frame: During construction

Responsibility: Implementation - EPC

Supervision - BBA

5. Environmental Impact/Issue: Noise and Vibration

Mitigation Measures: A Noise Monitoring Programme shall be set up to measure noise levels at the closest sensitive receptors as work starts on each new section along the route. If levels at receptors exceed specified standards, remedial measures shall be taken to reduce noise emissions to more acceptable levels. Lessons-learnt from preceding work sections shall be considered when setting up and performing the new sections of road works

Construction work will be restricted in between 0600 to 2100 hours of each date.

Maintenance of machinery and vehicles should be enhanced to keep their noise at a minimum level.

Noisy activities taking place within construction sites shall be located as far as possible away from sensitive receptors including homes, places of worship, schools and hospitals. In particular: crushers shall be located at least 50 m away from sensitive receptors; if piling is required within 100m of sensitive premises this shall be carried out using bored piling or casings driven by torque and hydraulic pressure excavation of hard materials within 50 m of sensitive receptors shall be carried out by hydraulic or electrical power (e.g. actuating rotary drills).

Time Frame: During construction

Responsibility: Implementation - EPC

Supervision - BBA

6. Environmental Impact/Issue: Labour Shed

Mitigation Measures: Provision of garbage bins and sanitary facilities will be made.

Special attention shall be paid to the sanitary condition of sheds.

Time Frame: During Establishment, operation and dismantling of sheds

Responsibility: Implementation - EPC

Supervision - BBA

7. Environmental Impact/Issue: Biodiversity and Nature Conservation

Mitigation Measures: Minimum damage or disruption to the flora. Trees or shrubs will be removed that impinge directly on the permanent works or necessary temporary works with prior approval from the Engineer

All works are to be carried out in such a fashion that the damage or disruption of the fauna is minimum

Time Frame: During Construction phase

Responsibility: Implementation - EPC

Supervision - BBA

8. Environmental Impact/Issue: Accidental Risks

Mitigation Measures: Safety tapes and signals will be installed and traffic rules and regulations will be actively enforced in the temporary diversions.

Time Frame: During Construction

Responsibility: Implementation - EPC

Supervision - BBA

9. Environmental Impact/Issue: Hazardous Materials

Mitigation Measures: Specialist chemicals used in tunnelling shall be selected to be of no or low hazard to environment

Selection, storage, use and disposal of hazardous materials shall be strictly controlled in accordance with legal requirements and good industry practice regarding worker health and safety, public health and safety and environmental protection. All procedures and related information shall be set out in the Waste

Management Plan: Relevant staff shall be trained in required measures.

Time Frame: During Tunnelling

Plan in place and implemented during construction

Responsibility: Implementation - EPC

Supervision - BBA

C. <u>Operation Phase</u>

1. Environmental Impact/Issue: Safety

Mitigation Measures: A comprehensive Emergency Preparedness and Response Plan (EPRP) shall be prepared for operation of the tunnel to address all foreseeable incidents including fire, explosion, road accidents, earthquake, flooding, activity and other threats. The EPRP shall be prepared in consultation with the local emergency services, and shall include plans to prevent, prepare for and respond to emergencies affecting road users (vehicles and pedestrians) and the community. All necessary information shall be conveyed to road users and the wider community

Time Frame: Prior to start of tunnel operation

Responsibility: Implementation - BBA

Supervision - BBA

2. Environmental Impact/Issue: Water Pollution

Mitigation Measures: All road and tunnel drainage shall be collected at sumps located at the low points along the route (at approach road and in the tunnel) and discharged to the proposed DAP drainage system in accordance with required permits.

Time Frame: During Operation

Responsibility: Implementation - BBA

Supervision - BBA

3. Environmental Impact/Issue: Waste

Mitigation Measures: All operational waste shall be managed in accordance with legal requirements, including wastes generated form treatment of road drainage and from clean up of spills

Time Frame: During Operation

Responsibility: Implementation – BBA/EPC

Supervision - BBA

4. Environmental Impact/Issue: Noise and Air Quality

Mitigation Measures: The Project shall work with the Deputy Police Commissioner (Traffic) and take other initiatives to encourage drivers to minimize emissions, e.g. regular vehicle inspections, appropriate driving behaviour

Proper traffic signs shall be used to provide information to drivers to facilitate smooth traffic flow to reduce noise and emissions, e.g.

	advice on driving speed, upcoming traffic, and general tips for minimizing vehicle emissions.
Time Frame:	During Operation
Responsibility:	Implementation – BBA/Traffic Police Supervision - BBA

BBA- Bangladesh Bridge Authority, PAP- Project Affected People, INGO- Implementing Non Government Organization, EPC-Engineering, Procurement and Construction

8.5.3 Roles of BBA safeguard unit for EMP Implementation

The roles of BBA safeguard unit for the implementation of EMP are as below:

- Monitoring progress of the project as per planned schedule of activities;
- Exercising oversight over the implementation of environmental mitigation measures by the contractors;
- Assisting the Site Engineers by providing appropriate environmental advice and solutions;
- Documenting the experience in the implementation of the environmental process;
- Preparing training materials and implementing programs in collaboration with the Consultant;
- Maintaining interfaces with the other line departments / stakeholders;
- Reporting to Donor (if applicable) and DOE on status of EMP implementation;
- Preparing budget and maintaining records of expenditure.

8.5.4 EMP Cost

Table 8.5.4-1 presents the budget proposed for environmental management of the project for the next detailed design and construction stages. The following assumptions have been made in exercising the budget:

(1) Cost for detailed design of Environmental Management and Monitoring Plan (EMMP) during detailed design stage includes the consultancy cost for the proposed professionals and environmental quality testing;

(2) Cost for implementation of EMMP during pre-construction and construction stages includes the personnel cost as well as environmental monitoring cost for selected environmental parameters;

(3) Environmental cost associated with site clearance, approach road construction, management of spoiled from tunnel construction etc. will come from associated civil construction cost. No environmental budgetary head for these issues will be considered.

(4) All costs for mitigating socio-economic environmental adverse impacts (Resettlement and Tree compensation and planting) as identified in this report

will go to RAP (Resettlement Action Plan) which in addition to Resettlement issues will also address socio-economic environmental issues. No environmentally budgetary head will be considered in this regard.

(5) Contractor will manage all general construction related environmental issues such as Environment, Health and Safety (EHS) issues through undertaking best environment-friendly international construction practice, i.e., Environmental Code of Practices, as a part of their construction works. Hence, Contractors will not be paid for practicing these ECPs.

(6) Contractors will bear all cost associated with professional input for management of his construction related EHS issues as a party of construction cost and hence contractors will not charge any additional money for this head.

Item	**Unit rate in BDT**	**man-months**	**Total cost in BDT**
Detailed design stage			
Human resource			
Sr. Environmental Specialist (1)	250,000	6	1,500,000
Jr. Environmental Specialist (1)	100,000	6	600,000
Sr. Independent Environmental Consultant/BBA (1)	250,000	2	500,000
Survey			
Environmental quality testing (air, ground water and surface water, noise, etc.)	Lump-sump		1,500,000
Ecological survey within 5 km radius of both end of tunnel alignment	Lump-sump		500,000
Climate change study conduct simulation under various climate change scenarios (based on Global Circulation Models, Data, subsequent localization and preserving linkages) and come up with a "credible design scenario".	Lump-sump		1,000,000
Implementation stage			
Pre-construction and Construction			
Human resource			
Sr. Environmental Specialist (1)	250,000	48	12,000,000
Jr. Environmental Specialist (1)	100,000	48	4,800,000
Sr. Independent Environmental Consultant/BBA	250,000	18	4,500,000
Survey			
Environmental quality testing (air, ground water and surface water, noise, etc.)	Lump-sump		500,000
Total budget			27,400,000
			27.4 million

Table 8.5.4-1 Proposed Budget for environmental management in the detailed design and implementation stages of the project

8.6 Climate Change

The Government of Bangladesh has a pro-active policy with regard to climate change. In 2008, the national "Climate Change Strategy and Action Plan" was published, prioritizing disaster risk reduction, decreasing of carbon emissions, and provision of adequate finance for mitigation of impacts.

It is widely accepted that human-induced climate change is under way (IPCC, 2001) and the future climate of Bangladesh, like much of the world, will be warmer. Obviously, coastal areas are one of the most vulnerable places due to sea-level rise, increased level of inundation and storm flooding, coastal erosion, seawater intrusion and increased temperature (Torresan et al., 2008). Evidence of the impact of recent global climatic changes on fisheries resources has already been observed, with reduced productivity in African lakes attributed to elevated late 20th century atmospheric temperatures (Vollmer et al., 2005), and increases in the frequency and severity of coral bleaching with rising sea surface temperatures in tropical and sub-tropical coastal zones (McWilliams, et al., 2005). The impacts of coral bleaching on fish communities include changes in their diversity, size and composition (Munday et al., 2008). Fish species distribution has also been altered in the North Sea due to recent increases in sea surface temperatures (Perry et al., 2005), and model projections show that climate change may lead to numerous local extinctions in the sub-polar regions, the tropics and semi-enclosed seas (Cheung et al., 2009). Anthropogenic climate change is thus already affecting aquatic ecosystems and the human societies that depend on them (Perry et al., 2009).

Data from six meteorological stations of central and southeast coast of Bangladesh shows the trend of seasonal changes in 20 years. Length of winter shows irregular variation with increasing trends of 45 and 34 days in Sandwip and Hatiya respectively. Length of summer gives increasing trends in all the stations with 22 days in Maijdee but decreases 2 days in Chittagong. Length of rainy season indicates decreasing trend in all stations with 19 days in Sandwip. Annual precipitation decreased in all stations with particular concern in Feni (486 mm) and Cox’s Bazar (222 mm).

As the proposed tunnel location is exposed to Bay of Bengal, there is possibility of tidal water flooding due to global warming and sea level rise. Climate change considerations will play a crucial role in the design of tunnel and its components. During Detail Design, the consultant will need to conduct simulation under various climate change scenarios (based on Global Circulation Models, Data, subsequent localization and preserving linkages) and come up with a “credible design scenario”. This climate change design will be subjected to EIA.

The main objective of climate change study is to assess the hydro-meteorological parameters that are directly and indirectly exposed to climate change phenomenon for facilitating the detail design and environmental impact assessment process. In this regard, the study will be assessed the effects of climate change on the river hydrology at the proposed tunnel site.

More details could be found from the Main Report.

8.7 Conclusions

The study of Environmental Impact Assessment was conducted to identify the significant environmental impacts for the tunnel construction along with mitigation measures. The EIA report is a legal requirement for obtaining Environmental Clearance Certificate from the Department of Environment (DoE) for implementation of proposed Multilane Tunnel Project at Patenga-KAFCO end under river Karnaphuli. The information and data presented in the EIA are based upon documents provided by design consultants, and specific data obtained and gathered from relevant organizations/institutions, field survey and public consultation meetings in the study area in line with the Environmental Guidelines, (Volume 1) published by RHD as well as the EIA guidelines for industries published by DOE of the GoB.

Construction work, including tunnel construction, will generate a number of negative impacts on the environment. Many of the impacts during the construction period for project cannot be assessed at this moment, because sites for temporary work activities have not been identified and/or information concerning the period and the duration of these activities are not available. The temporary construction works could create more impacts than the activities related to the permanent works. For this reason, environmental management and monitoring program is developed for both temporary and permanent works covering preconstruction, construction and operation stages.

The key impacts which were identified and are addressed in the EIA are land loss, involuntary resettlement, spoil waste, air and noise quality, disturbance during construction, construction pollution, management of the construction workforce and workers health and safety, management of accidents and emergencies.

As the proposed tunnel location is exposed to Bay of Bengal, there is possibility of tidal water flooding due to global warming and sea level rise. Climate change considerations will play a crucial role in the design of tunnel and its components.

Implementation of appropriate environmental management plan and mitigation measures during various phases will minimize the negative impacts of the Project to acceptable levels. To ensure that these plans and mitigation measures are implemented and negative impacts avoided, the EMP will be included in the contract documents of the Project with a separate line item on environmental management in the bills-of-quantities.

Since the Project sponsor shows positive approach towards environmental management and safety standard more in-line with their environmental policy and management plan, it is expected that the BBA will provide necessary resources along with Safeguard Division like proper technical personnel with monitoring equipment to make accountable and responsible system for successful implementation of the recommended EMP recorded in the EIA Study.

Necessary environmental clearance should be obtained for the project before start of construction work. As this EIA has prepared during feasibility study, this will be further updated during the detailed design stage based on the detailed engineering designs.

Finally, having reviewed all the potential environmental impacts and following the recommended mitigative measures as per this ESMP, the proposed Multilane

Tunnel under the river Karnaphuli project is expected to proceed without having unacceptable environmental effects.

9. ASSESSMENT ON RESETTLEMENT REQUIREMENTS AND PREPARATION OF ACTION PLAN

9.1 Scope and Objectives

The major international donors like Asian Development Bank (ADB) and World Bank require that if the screening or social assessment determines that people will experience resettlement impacts a time-bound action plan with appropriate budget provisions is to be prepared and incorporated as an integral part of project design. The Resettlement Action Plan (RAP) will addresses both land acquisition and resettlement issues within the legal framework of the Government of Bangladesh (GOB) and Donors' policy on involuntary resettlement and covers the Affected Persons (APs) under resettlement/rehabilitation program providing income restoration and poverty reduction assistance to the eligible APs and the poor and informal settlers on the ROW. Thus, the RAP approach incorporates (i) land acquisition and resettlement issues; (ii) impact mitigation with special attention to the women and vulnerable groups and (iii) income generation support to the eligible members of the AP families and (iv) poverty reduction assistance to the poorest section of the people.

The policy requires that a plan would be prepared that sets out all of the compensation and rehabilitation support to be provided to any person, family or household who on account of the execution of the project would have his, her or their:

- Standard of living adversely affected;
- Income earning opportunities, business, occupation, work or place of residence or habitat adversely affected temporarily or permanently;
- Right, title or interest in any house, or interest in or right to use any land including premises, agricultural and grazing land, commercial properties, tenancy, or right in annual or perennial crops and trees or any other fixed or moveable assets, acquired or possessed, temporarily or permanently; and/or
- Social and cultural activities and relationships and other losses that may be identified during the process of resettlement planning.

The objective of the RAP is to provide a strategy for providing Project Affected Units (PAUs) with compensation for lost land, structure, trees, etc at replacement cost and restoration of income levels/living standards either through a compensation and rehabilitation package that ensures that PAUs are not left in a position where they are worse off with the project than without it. Thus, in accordance with Donors' policy, resettlement plan, depending on the magnitude of impacts have been prepared.

9.2 Methodology

A census and socioeconomic survey have been conducted and database has been prepared for resettlement action plan. The survey is also associated with stakeholders' consultation and property valuation survey.

The adverse impacts include land acquisition and displacement of households, shops, and community structures. The data gathered during the survey has been entered onto an electronic database which identified each Affected Household (AH) and the way they are impacted and losses they incurred. The objective of the census and socioeconomic survey was to establish a detailed inventory of the households and physical assets to be affected by the project; develop a socioeconomic profile of the AHs and Affected Persons (APs). The surveys also serve as a benchmark for monitoring and evaluation.

The census and a socio-economic survey have been carried out to provide requisite details on the Project Affected Units (PAUs) to further assess the magnitude of likely impacts and to identify measures for mitigation of adverse impacts. The survey included (i) full socio economic survey of the households, other physical units (shops, community units, etc.); (ii) surveys for land valuation and other assets; (iii) sketch mapping of the affected communities and (iv) community based public consultation with different communities along the right of way. The survey identified the households, commercial and business enterprises and common property resources on project right of way land (private and public), and other facilities. In addition to that, video film of the structures on the final alignment will be prepared to prevent any fraudulent claims in the future. The socioeconomic survey has collected a wide range of data, for example, demography, age/sex distribution, education, occupation, income/poverty data, types of businesses, types and ownership status of affected structures and other assets. **Table 9.2-1** shows distribution of impacts by locations. More information could be found from the Main Report.

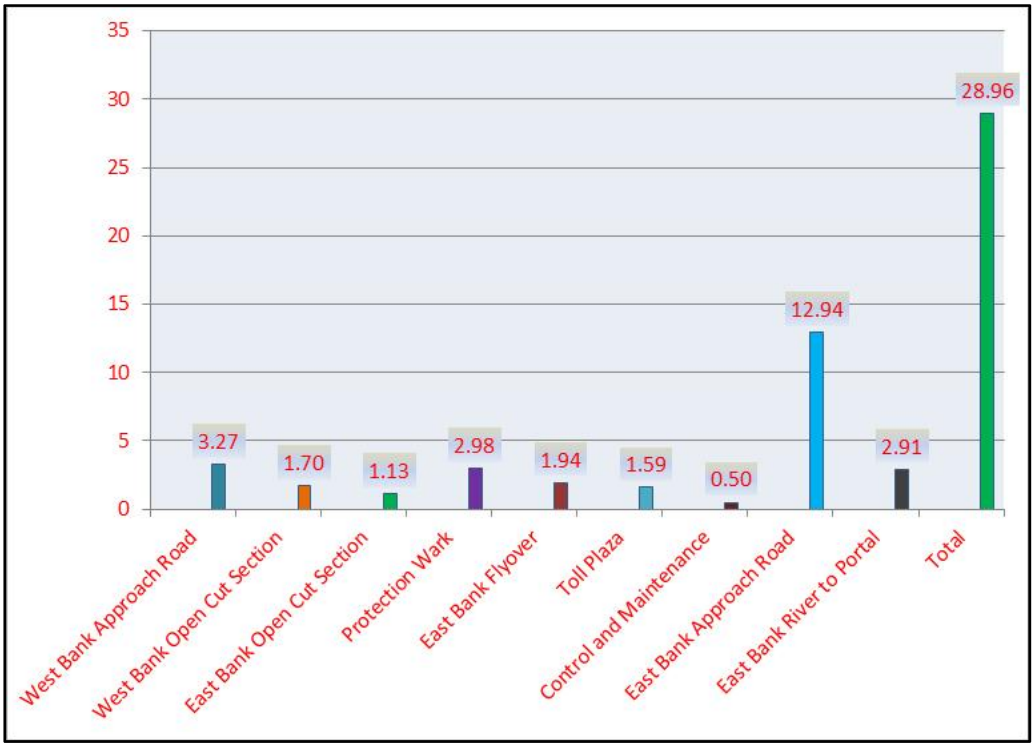
Sl. No.	Issues	Location		Total
		Patenga end	KAFCO end	
01	Length of the tunnel			3,050m
	Length of the approach road	740m	4,952m	5,692m
02	Quantity of land to be acquired (Acre)			
	Private land	4.72ha	6.81ha	11.53ha
	Land owned by CUFL		14.40ha	14.40ha
	Land owned by KAFCO		1.99ha	1.99ha
	Land owned by other organization	0.25ha		0.25ha
03	Number of total PAUs	28	493	521
04	No of HHs losing residential structure	02	37	39
05	No of affected Tenants HHs	0	38	38
06	No. of HHs losing commercial enterprises	21	277	298
07	No. of affected tenants businessmen	4	127	131
08	No. of Common properties resources (CPR) affected	1	14	15

Table 9.2-1 Distribution of Impacts by locations

9.3 Land Acquisition and Resettlement

9.3.1 Scope of Land Acquisition

As identified in the socio-economic survey, majority of the project affected units are located in KAFCO end where about 4.5 km approach road has been proposed. Besides, service area, toll plaza and portal, open cut section etc. are the project components. Considering all components of the project about 28.96 ha land would be required of which 3.27ha for West Bank approach road, 1.70 ha for west bank open cut section, 1.13 ha for east bank open cut section, 2.98 ha for Bank protection work, 1.94 ha for east bank flyover, 1.59 ha for toll plaza, 0.50 ha for control and maintenance, 12.94 ha for east bank approach road and 2.91 ha for east bank river to portal section of the tunnel alignment. The east approach road from KAFCO gate to Chaturi Chowmuhini bazaar is owned by Chittagong Urea Factory Limited (CUFL). CUFL had acquired land in 1979-80 for construction of their approach road for carrying Urea and other products. The land has been published in gazette in 2011 in favour of CUFL. Extra land will be required for widening and straitening of the road for the tunnel approach. **Figure 9.3.1-1** presents component wise quantity of land in hectare.



Source: Socioeconomic survey conducted by KMC in April-May 2012

Figure 9.3.1-1 Component wise quantity of land to be acquired for the project

9.3.2 Resettlement and Other Impacts

In addition to land acquisition, the works will require resettlement of 343 project affected units (PAUs) of which 33 residential households (15 on own land and 18 are on government, other lands as squatters/uthulies), 286 commercial enterprises (20 on private land and 266 on government or other lands) and 18 common

property resources such as Mosque, Madrasah, Cremation ground, Union Parishad office, Graveyard, School, Billboards, Eidgah, Club, etc. which are mostly located on government, CUFL or other lands and 4 are located on private land. As per survey result a total of 27 tenant residential households, 48 tenant businessmen and 146 wage labours will lose their income sources due to the project. About 239 people will be resettled due to loss of residential households.

9.3.3 Significance of Impact

In terms of significance of impact, an estimation of 60 residential households (15 on own land and 18 squatters and 27 tenants) and 334 commercial/business premises (20 on own land and 266 squatter and 48 tenants) will be affected. A total of 146 wage employees will be losing their livelihood due to the project. It is mentionable that 28.17 ha land will be affected by this project. Name and profile of the land owners would be finalized at detailed design stage of the project. Plot numbers with quantity of land in each plot and affected portion of the plot have been calculated in Land Acquisition Plan (LAP). About 239 people will be displaced due to loss of homesteads and 1,367 people will be affected by losing Commercial and Business Enterprises (CBEs). Besides, 18 common properties such as mosque, school, graveyard, club, cremation ground, etc. are affected by the project interventions.

Household members of the tenants and wage laborers will also be impacted by the project. In addition, some people who involved in small business like mobile vendors, products/goods suppliers, and the like at Chaturi chowmuhini bazaar would be indirectly impacted by the project. A huge quantity of population will cumulatively be impacted by the project. All of these impacts would be addressed and mitigated through updating of this RAP in detailed design stage of the project. The AHs experiencing significant impacts are shown in **Table 9.3.3-1**.

	Patenga end (West)	**KAFCO end (east)**	**Total**
AHs being displaced	02	75	77
AHs losing business	25	404	429
Number of employees will be losing job	20	126	146

Table 9.3.3-1 AHs Experiencing Significant Impacts

Source: Socioeconomic survey conducted by KMC in April-May 2012

9.3.4 Special Measures for Vulnerable Groups

Vulnerable groups to be affected by the project include (i) female headed households and female APs who are poor or otherwise disadvantaged; (ii) elderly headed households; (iii) poor households; and (iv) the landless. Special assistance will be required to support these vulnerable AHs including additional subsistence and relocation assistance, opportunity for skill training and income restoration through facilitating or providing micro-credit.

9.4 Legal and Policy Framework

9.4.1 Policy on Involuntary Resettlement

The Asian Development Bank's (ADB) Policy of Involuntary Resettlement (1995) on the other hand, recognize & address the Resettlement &Rehabilitation impacts of all the affected persons irrespective of their titles and requires for the preparation of RAP in every instance where involuntary resettlement occurs.

9.4.2 Types of Losses and Impact Category

The types of losses due to undertaking of the project include (i) loss of land (homestead, vita/high land, agricultural and pond); (ii) residential/ commercial/ community structures; (iii) loss of trees and crops; (iv) loss of work days/incomes due to dislocation and relocation of households and businesses, (v) loss of rental premises and (viii) loss of access to land and premises for residence and trading.

9.4.3 Principles, Legal and Policy Commitments

The RAP has the following specific principles based on the government provisions and ADB policy:

- The land acquisition and resettlement impacts on persons affected by the subprojects would be avoided or minimized as much as possible through alternate design options;
- Where the negative impacts are unavoidable, the persons affected by the project and vulnerable groups will be identified and assisted in improving or regaining their standard of living;
- Information related to the preparation and implementation of resettlement plan will be disclosed to all stakeholders and people's participation will be ensured in planning and implementation. The resettlement plan will be disclosed to the APs in local language;
- Land acquisition for the project would be done as per the Acquisition and Requisition of Immovable Property Ordinance 1982 and subsequent amendments during 1993-1994. Additional support would be extended for meeting the replacement value of the property; the affected persons who does not own land or other properties, but have economic interests or lose their livelihoods will be assisted as per the broad principles described in this document;
- Before taking possession of the acquired lands and properties, compensation and Resettlement and Rehabilitation (R&R) assistance will be paid in accordance with the provisions described in this document;

An entitlement matrix for different categories of people affected by the project has been prepared. People moving in the project area after the cut-off date will not be entitled to any assistance. In case of land acquisition the date of notification under section 3 for acquisition will be treated as cut-off date. For non-titleholders such as informal settlers / squatters and encroachers the date of census survey or a similar designated date declared by the executing agency will be considered as cut-off date.

Appropriate grievance redress mechanism will be established to ensure speedy resolution of disputes.

All activities related to resettlement planning, implementation, and monitoring would ensure the involvement of women and other vulnerable groups.

Consultations with the APs will continue during the implementation of resettlement and rehabilitation works.

There should be a clause in the contract agreement that the construction contractor will compensate any loss or damage in connection with collection and transportation of borrow-materials.

In accordance with the resettlement principles suggested for the Project, all affected households and persons will be entitled to a combination of compensation packages and resettlement assistance depending on the nature of ownership rights on lost assets, scope of the impacts including socio-economic vulnerability of the affected persons and measures to support livelihood restoration if livelihood impacts are envisaged. The affected persons will be entitled to (i) compensation for the loss of land, crops/ trees at their replacement value; (ii) compensation for structures (residential/ commercial) and other immovable assets at their replacement value; (iii) assistance for loss of business/ wage income; (iv) assistance for shifting, and (v) rebuilding and/ or restoration of community resources/facilities.

This will ensure that persons affected by land acquisition; whether titled or non-titled will be eligible for appropriate compensation/resettlement benefit. Persons having no legal title but using the land under acquisition if vacated for the Subproject purpose would be provided with compensation and resettlement benefit for structures and shifting/reconstruction allowance. Households having customary rights to land and physical property like the owners and users of vested and non-resident property, lessees of homestead, commercial and agricultural land, sharecroppers, renters of land and structure, etc. are also covered under the resettlement action plan. The RAP also includes opportunities for occupational skill development training for income generation activities for the APs, especially for poor households. The people involuntarily displaced from homes, assets, or income sources as well as non-titled people affected by the project will receive priority access to these income restoration measures. The resettlement activities of the Project will be carried out in consultation with the APs and all efforts will be made to minimize disruption during project implementation. APs preferences will be taken into account in the selection of alternative relocation sites.

9.4.4 Eligibility Policy and Entitlement Matrix

9.4.4.1 Eligibility Criteria

All APs will be entitled to compensation and resettlement assistance based on severity (significance) of impacts. [8] Nevertheless, eligibility to receive compensation and other assistance will be limited by the cut-off date. The cut-off date for compensation under law (Ordinance II of 1982 and its 1994 amendments)

8 The severity of impacts is based on the difference between temporary and permanent effects and minor and significant impacts as defined in ADB's Policy and the Glossary of Terms.

is considered for those identified on the project right of way land proposed for acquisition at the time of service of notice under Section 3 or joint verification by DC whichever is earlier. The cut-off date of eligibility for resettlement assistance under this RAP is the commencement date of the census which is the 11 April 2012 at KAFCO and 12 April 2012 at Patenga. The absence of legal title will not bar APs from compensation and assistance, as specified in the entitlement matrix.

Structures located on non-titled land or GOB land, if displaced, will be entitled for compensation under the Project. Vulnerable APs or AHs will qualify for additional assistance to facilitate them relocation and restoration of their livelihoods.

Non-vulnerable households with structures affected will be entitled to compensation for structures and assistance for shifting and reconstruction of the same. Any structure not directly used by a non-vulnerable household i.e. rented out for income will also not qualify for additional resettlement assistance.

9.4.4.2 Compensation and Entitlement Policy

An Entitlement Matrix has been prepared on the basis of census and socioeconomic survey conducted in April-May 2012. It identifies the categories of impact based on the census & SES and shows the entitlements for each type of loss. The matrix describes the units of entitlements for compensating the lost assets, and various resettlement benefits. Cash Compensation under law (CCL) for lost assets (land, tree, structure & other physical establishments) will be accorded to the owners through the DCs as per market value assessed through legal procedure. The resettlement benefit for indirect losses and difference between replacement value and the CCL will be paid by BBA through RAP Implementing Agency.

9.5 Resettlement Action Plan

9.5.1 Relocation Resettlement and Income Restoration

9.5.1.1 Scope of Displacement and Relocation

According to the census & SES data, implementation of the project will require displacement of 343 project affected units (PAUs) including 50 residential households (15 on own land, 18 squatters and 27 tenants) 334 commercial enterprises (20 on private land, 266 squatters and 48 tenants) and 22 common property resources such as mosque, school, graveyard, eidgah, club, cremation ground, billboards, etc. at Patenga and KAFCO end of the project. The affected households and other entities are primarily encouraged for self relocation. Nevertheless, the RAP has kept provision for relocation of the affected households and business enterprises in a resettlement site. The resettlement site may be located at Chaturi mouza under Anwara Upazila or adjacent area to facilitate affected shops at Chaturi Chowmuhini intersection. During consultation meetings the shop owners demanded relocation in a particular site with some civic amenities rather cash compensation so that they restore their previous standard of living by doing business.

The project may provide some civic amenities in the resettlement site such as land development, tube well, water sealed latrine, internal road, etc. The vegetable shops affected by the project may be relocated under open shed in the resettlement site. The area in sft for each of the vegetable shop would be determined by the BBA during implementation of the project. Other categories of shops may be allotted 160 square feet area for reestablishing their business structure. It is mentionable that there are about 780 trees in different species and sizes are required to fell down of which 66 at Patenga End 714 at KAFCO end. All of the affected residential households are losing their entire structures. Businessmen are losing total business units but not losing their homestead. Among the CBEs most of them are small business with temporary sheds made of CI sheet and wood/bamboo/Polythin, etc. About 239 people will be displaced due to loss of housing structure (living on own land and squatters).

9.5.1.2 Relocation of Housing and Other Establishment

The project is taking land for construction of the tunnel with approach road, toll plaza, service area, flyover, portal, etc for facilitating easy communication with Cox's Bazar and other parts of Chittagong region with whole Bangladesh. A total of 60 residential households of which 15 on own land and 18 squatters and 27 tenants and 334 commercial/business premises including 20 on own land and 266 squatter and 48 tenants. A total of 146 wage employees will lose their livelihood due to the project. The project will therefore encourage "self-relocation" by affected households selecting replacement homestead land in the vicinity of their own. The objective is to minimize social disruption in the resettlement process and allow people to remain together within kin groups for mutual support. Besides, the project will arrange resettlement site(s) at KAFCO end for residential households and commercial enterprises with required civic facilities.

According to the nature of the affected business enterprises and residential households and considering other project experience it is estimated that only displaced households living on own land would be eligible for 5 decimal land in resettlement site by paying CCL money to BBA and 2.5 decimal land would be provided to squatters households free of cost. The commercial enterprises would be provided 160 square feet each irrespective of land owners and squatters for relocation in the resettlement site. Apart from this, 50% extra land has been considered for common use such as road, mosque, etc. Considering all, a total of 1.36 ha land would be required to relocate all houses and commercial enterprises. The required budget for this land and resettlement sites development and other costs would be incorporated in the RAP budget during updating of the RAP in detailed design stage.

9.5.1.3 AP Preference for Relocation

9.5.1.3.1 Households wanted Assistance for Relocation

During the census survey, the relocation choices of the affected persons were enumerated. The households to be relocated are homestead loser prefer to remain in the adjoining area of the project location to continue their present occupation. All of the affected households and shops owners demanded relocation in the project sponsored relocation site. Therefore the RAP has kept provision for

relocation of the affected households and shops in a resettlement site may be located at Chaturi Mouza of Anwara Upazila.

9.5.1.3.2 CBEs wanted Assistance for Relocation

All of the commercial enterprises preferred relocation in the project sponsored relocation site so that they can continue their business uninterruptedly. Most of them expressed during consultation meeting that this is their only source of income and some 5-10 households are depending on some medium or large scale business enterprises such as saw mill, hotel, etc. They even prefer relocation with all civic facilities rather they will be paid for business in cash. It is mentionable that, at Patenga end The CDA has been implementing city ring road project which has a provision of resettlement site for the shops at Patenga. The affected shops of the tunnel project at Patenga end may be relocated in the city ring road project's resettlement site if it is being integrated with that project. The project authority (CDA) may be consulted regarding this matter. For relocation of the shops at Chaturi Mouza, about 1.36 ha land would be required that would be kept in the land acquisition plan during detailed design stage of the project.

9.5.1.4 Replacement of Agricultural Land

About 7.51 ha agricultural land would be required to acquire for various components of the project such as tunnel approach road, toll plaza, service area, portal, etc. of which 2.98 ha at Patenga end and remaining are at KAFCO end. The AHs will be paid cash compensation at replacement value of the land. The stamp duty and registration cost for purchasing of replacement land will be refunded. DC will compensate for lost trees and crops at the rate estimated by the Department of Forest (DOF) and the Department of Agriculture Extension (DAE) respectively and confirmed through consultation and market appraisal.

9.5.1.5 Income and Livelihood Restoration Strategy

Mitigation of loss of assets and livelihood is the main focus of the resettlement plan. Additional measures will be taken to provide appropriate support to the livelihood restoration aspects of affected households (AHs). According to the known impacts, AHs will be relocated and will lose income from wages and business operation during the re-establishment period. Other AHs will lose access to agricultural land, crops and other assets. Adequate compensation will be awarded to these AHs before relocation. In addition, vulnerable APs will receive other support and also get preference for employment in civil construction works.

In compliance with the RAP, the RAP will identify resources, in addition to compensation, for income restoration assistance. This will be through linking resettlement activities with a Livelihood and Income Restoration Program (LIRP) to be designed during detailed design stage of the project.

The RAP includes the following categories of AHs for income restoration and livelihood support:

- Vulnerable households to be relocated from the project right of way. Eligible members of such family will be identified during planning the LIRP;

- Vulnerable households having no adult male members to shoulder household responsibility (women headed households). The women heading the household will preferably be the eligible member;
- Vulnerable households of the employees and daily wage earners of the diminished businesses or their nominated representatives;
- Vulnerable households losing access to agriculture land including sharecropper, and leaseholders;
- Vulnerable households losing access to commercial land including business proprietorship; and
- Vulnerable households losing more than 10% of their productive assets due to the project

For additional support to usual income restoration assistance as mentioned above, the RAP Implementing Agency (IA) will specifically undertake assessment of needs and skill base of vulnerable APs of age between 15 to 60 years. The IA will recommend the eligible members of affected vulnerable households with their relevant profile to the LIRP implementing organization through BBA. The short-term livelihood regeneration assistance under the RAP and long-term income generation program under the LIRP will be organized as follows:

1. Eligible members of poor households to be relocated from the project right of way.	1.1 Short-term: Compensation for land, structure & trees, shifting allowance, reconstruction assistance, cash assistance for loss of workdays due to relocation, and priority in employment in construction. 1.2 Long-term: Needs and capacity identification, human development and skill training, institutional support under the LIRP.
2. Eligible members from poor female headed households having no adult male members to shoulder household responsibility.	2.1 Short-term: In addition to support as 1.1, additional subsistence allowance. 2.2 Long-term: As 1.2 above.
3. Poor and vulnerable employees of affected businesses.	3.1 Short-term: Subsistence for loss of income and employment. 3.2 Long-term: As 1.2 above.
4. Eligible members of poor households losing access to agriculture land including sharecropper, and leaseholders.	4.1 Short-term: Compensation for crops. 4.2 Long-term: As 1.2 above.
5. Eligible members of poor households losing access to commercial land including	5.1 Short-term: Compensation for loss of business income, shifting and reconstruction assistance.

business proprietorship.	5.2 Long-term: As per need, livelihood and income generating training and employment in construction.
6. Eligible members of poor households losing more than 10% of their productive assets.	6.1 Short-term: Compensation for crops, replacement value of land, assistance for land purchase, and employment in construction. 6.2 Long-term: As 1.2 above.

Table 9.5.1.5-1 Livelihood Restoration Options

9.5.1.6 Capital Support

Funds for income restoration programs become a major constraint to the project affected people utilizing their skill obtained/enhanced through IGA training. Capital support for potential income generation activities to the trained and efficient target group people will therefore be provided from the project as a lump sum amount of BDT 20,000 (twenty thousand) per person after having training. Further capital support may be provided by any source i.e. banks, NGOs, Samitee, etc. arranged by the APs in the form of credit.

9.5.1.7 Employment in Construction

Local people whose livelihood is impacted by the project will get preference in jobs associated with the project construction. Female affected people will form labor contracting society (LCS) with the help of IA and be deployed by the Contractor in road slope turfing, watering, tree plantation, etc. or any other suitable works. Affected persons will get preferential employment in project civil works based on their eligibility. The jobs, in the semi-skilled and unskilled category, shall be offered to the APs in preference to the other. A clause should be incorporated in the contract documents requiring contractors to give employment, if available, to project affected people having EP ID cards in preference to other persons.

9.5.2 Implementation Arrangements

9.5.2.1 Role of Resettlement Unit (RU)

BBA-RU will be stationed at the BBA headquarter in Dhaka. A total of two field offices will be opened – one in Patenga (West) end and another at KAFCO (East) end of the Karnaphuli river. The Key personnel include, additional director (safeguard division), executive engineer – resettlement, deputy director – la & r, m&e, assistant engineer – resettlement, deputy commissioners' office(s), rap implementing agency/ngo, project supervision consultants and external monitoring agency.

9.5.2.2 Committees in Implementation of the RAP

The MOC will form a Property Assessment and Valuation Committee for the project through a gazette notification to verify, compare and review the physical verification data conducted by Implementing Agency with the DCs' assessment of

loss of physical assets and their owners. The PAVC will also be responsible for determining replacement value of the affected properties. The scope and responsibility of the PAVC will be clearly defined in the gazette. The implementing Agency will process the entitlements of the project-affected persons using the joint verification survey (JVS) data as one of the determinants.

9.5.3 Resettlement and Compensation Costs and Budget

9.5.3.1 Budgeting and Financial Planning

Resettlement funds would be provided either by the EA or the Donor based on the financing plan agreed by the Government of Bangladesh and Donor. Land acquisition, compensation, relocation and rehabilitation of income and livelihood will be considered as an integral component of project costs. The rehabilitation and training to the potential affected persons will be provided under the LIRP based on vulnerability and needs assessed through a special census and consultation exercise.

The estimate for land acquisition by the DC will be prepared by his/her LA section and placed to the BBA for transfer of the fund to the account of the DC. The additional benefits as per the policy will be paid by the BBA with the assistance of RAP Implementing Agency. However, the Implementing Agency will assess the quantity of losses and the eligible persons for resettlement benefits and produce a resettlement budget to BBA for approval and periodic release.

The RU of BBA will ensure that the land acquisition and resettlement budgets are delivered on time to the DC and the Implementing Agency (IA) account for payment of resettlement grant. The RU will also ensure that the RAP should be submitted to Donor for approval, and that fund for compensation and entitlement under the RAP are fully provided to APs prior to the award of the civil work contract.

The RAP budgets for compensation for land, structures, other assets, crops and trees, and special assistance will be calculated using the market rates reflecting replacement cost at the time of dispossession. The costs for relocation and special assistance will be consistent with the resettlement policy. Other costs involving cost of the RAP implementing agency that include project disclosure, public consultations and focus group discussions, etc. Resettlement site development, operation cost of the Independent Monitor, training on IGA and cash grant, etc. are also included in the RAP budget. There is also a budget allocation for 10% as contingency.

The total estimated cost for implementation of the RAP for both KAFCO and Patenga end is BDT 3,887,364,642 equivalent to US$ 47,639,273 (USD $ 1= BDT 81.6) including CCL amount to be determined by the DC for land and other physical assets. These estimates and the budget must be regarded as provisional, given the need for updating the RAP during detailed design and implementation stage. Final rates per unit for land, structures, trees and other affected properties will be determined by the PVAT. Based on the rate and RAP policy a final resettlement budget would be prepared and approved by the EA. The total estimated budget as summary is shown in the **Table 9.5.3.1-1** below.

Item No.	Head	Amount
A	Compensation for land	3,074,018,740
B	Stamp Duty & Registration Cost @ 7.5% of the land value	230,551,406
C	Transition Allowance (one time) for 1 year @ BDT 40000 per acre	1,459,600
D	Compensation for structure	140,377,030
E	Compensation for Trees	1,207,950
F	Compensation for fruits (30% of timber value of fruit bearing trees	630,600
G	Saplings distribution among the affected HHs (5 nos. for each HH)	126,500
H	Compensation for Crops	1,237,000
I	Other Resettlement Benefits	22,576,215
J	Resettlement site development	20,000,000
K	Operation cost for RAP implementing Agency	50,000,000
L	Operation cost for Independent Monitor	5,000,000
M	Contingency @ 10% of the Sub-total A-F	340,179,601
	Grand Total	3,887,364,642
	USD	**47,639,273**

Table 9.5.3.1-1 Estimated Budget for Land Acquisition and Resettlement

9.5.3.2 Assessment of Unit Value for Compensation

The valuation survey registered recent transacted price of land and construction cost of the different categories of structures by interviewing local people including potential sellers, buyers, religious leader, etc. The conclusion of the survey is that in most cases the actual transaction values are higher than the values officially documented and registered.

9.5.3.3 Approval of the Resettlement Budget

Land acquisition and resettlement budget included in the RAP will need to be approved by the Ministry of Communications. Upon approval of land acquisition by Ministry of Land, the DC will prepare estimates for compensation including service charge and produce that to the BBA for placement of fund within 60 days.

The rates for compensation and cash entitlements for rehabilitation as well as allowances payable to AHs will be adjusted annually, based on the actual annual inflation rate. BBA will determine the annual inflation rates to be applied to all cash entitlements in each year.

The RAP implementing agency will assist RU, (BBA) to prepare resettlement budgets covering all eligible loss and entitlements confirmed through joint verification and determination of replacement market price of land and property by PVAT.

9.5.3.4 Management of Compensation and Flow of Awards

The BBA has a safeguard division in its head quarter which is staffed with experienced and qualified consultants and officials. Now the BBA is implementing resettlement plans for Padma Bridge Project and paying compensation to the affected persons as per RAP policy. There is a detailed administrative guideline (payment modality) in Padma Bridge Project. The same types of modalities are required to implement the RAP for Karnaphuli Tunnel Project. The modalities will be prepared during detailed design stage of the project. The BBA and the RAP implementing agency will strictly follow the administrative guideline after its approval from the Project Director. The modality should include definition of various resettlement terms, the entitlements, detail procedure for identification of eligible persons for resettlement entitlements of the RAP, and assess loss and entitlement of individual APs, process of payments, affecting their disbursement and documentation.

The RU with requisition of payments from the Executive Engineer (Resettlement) as per EP payment list to be prepared by the RAP implementing agency - will place fund with Executive Engineer (Resettlement) at the field level. The administrative guidelines will contain details of the management aspects and monitoring mechanism. The Assistant Engineer, BBA and authorized representative from IA will sign the vouchers. Payment will be made and records maintained as per approved administrative guidelines.

Compensation under law for land acquisition will be paid to the legal owners of land and property by the concerned Deputy Commissioner's LA section. DC will prepare individual cheques accompanied with receiving copies of payment and undertaking note.
The IA will collect CCL copy from the DC office and prepare statement, entitled person's file, entitlement card, indent and other necessary documents for making payment of resettlement benefit. In case of non-titled holder, the IA will prepare all necessary documents based on the joint verification survey data and arrange payment of resettlement benefit to the EPs.

9.5.4 RAP Implementation Schedule

A time-bound implementation schedule for the RAP has been prepared with an assumption that the construction of the tunnel may start in mid 2015. The implementation schedule will be finalized considering possible changes of events during detailed design and implementation period of the project. The APs will be paid their resettlement cash payments independent of legal compensation before their relocation and payments related to award of compensation by DC.

Sl. No.	Land Acquisition &Resettlement Activities	Start Date	Completion Date
1.	Deployment & Orientation of IA	January 01 '15	January 31 '15
2.	Information Campaign	February 01 '11	November 30 '19
3.	Formation of Committees (PAVC, GRC, etc.) by MOC	February 01 '15	March 31 '15
4.	Design/Development of RP	February 01 '15	April 30 '15

Sl. No.	Land Acquisition &Resettlement Activities	Start Date	Completion Date
	Implementation Tools		
	Preparation of the Land Acquisition Proposal by BBA and submitted to DC, Chittagong	January 01' 15	March 31 '15
5	Notice u/s 3 to be served by DC	April 01'15	April 30 '15
6	Property Assessment and Valuation survey by PAVC	April 01 '15	June 30 '15
7	Preparation and Submission of Estimate by DC	July 15 '15	August 31'15
8	Placement of fund with DC by BBA	September 15 '15	October 31, 15
9	Payment of CCL by DC	November 01, 15	June 30'19
10	Land handing over by DC to BBA and then to Contractor	December 01, 15	December 31, 15
12.	Data Processing and Determination of Individual Entitlements based on DC's payment and RAP policy by IA	January 01 '16	January 31 '16
13.	Preparation & Submission of Resettlement Budget by IA to BBA	July 01 '15	July 31 '15
14.	Approval of Resettlement Budget by BBA	August 01 '15	August 31 '15
15.	Payment of compensation/resettlement benefits by BBA through IA	September 01 '15	November 30 '19
16.	Redress of Grievances	June 01'15	October 31 '19
17	Payment of other Resettlement benefits based on GRC decision	October01 '15	November 30 '19
18	Relocation of HHs, CBEs & CPRs	October 01 '15	December 31 '15
19	Training and Income Generation Programs	January 01 '16	June 30 '19
20	Monitoring and Evaluation	March 01 '15	November 30 '19
21	Submission of project completion report by IA	December 01 '19	December 31 '19

Table 9.5.4-1 RAP Implementation Schedule – Period: January 2015 – December 2019

9.5.5 Grievance Redress Mechanism

9.5.5.1 Grievance Redress Committees

Implementation of the project will cause land acquisition, displacement, loss of livelihood, etc. those will require mitigation in a transparent manner. The grievances would be resolved within 21 days from the date of lodging the complaints.

Step 1	The Implementing Agency informs APs about their losses and entitlements If satisfied, the AP claims resettlement payments to the EA. If confused,
Step 2	The AP approaches the IA field level officials for clarification. The IA will clarify the APs about their losses & entitlements as per RAP. If resolved, the AP claims resettlement payments to the EA. If not resolved,
Step 3	The AP approaches to the GRC. IA staff assist the APs producing the complaints and organize hearing in 21 days of receiving the complaints.
Step 4	GRC to scrutinize applications, cases referred to DC through EA if beyond their mandate as per scope of work
Step 5	If within the mandate, GRC sessions held with aggrieved APs, minutes recorded. If resolved, the Project Director approves. If not resolved,
Step 6	The AP may accept GRC decision, if not, he/she may file a case to the court of law for settlement.
Step 7	The GRC minutes, approved by the Project Director, received at Conveners' office back. The approved verdict is communicated to the complainant AP in writing. The AP then claims resettlement payments to EA

Table 9.5.5.1-1 Steps of Redressal of Grievance

9.5.6 Monitoring and Evaluation

9.5.6.1 Supervision, Monitoring and Evaluation

BBA as the EA, through the RU, will establish a monitoring system involving the Additional Director, Safeguard Division and Deputy Director (LA&R, M&E), Consultants and the RAP Implementing Agency for collection, analysis, reporting and use of information about the progress of resettlement, based on the RAP. These stakeholders will be made responsible to monitor the progress of all aspects of land acquisition/ resettlement and income generation. The EA will report to the Donor on land acquisition, resettlement and income regeneration by APs in the quarterly reports, including identification of significant issues. Besides, an annual report stipulating all efforts and outcome will be sought by the Donor from the BBA.

The RAP implementation monitoring will be done both internally and externally to provide feedback to RU (BBA) and to assess the effectiveness. Mid-term reviews of the resettlement activities drawing upon monitoring and evaluation reports and other relevant data to identify any action needed to improve resettlement performance or respond to the changing circumstances. Evaluation of the resettlement activities will be resorted to during and after implementation of the RAP to assess whether the resettlement objectives were appropriate and whether they were met, specifically, whether livelihoods and living standards have been restored or enhanced. The evaluation will also assess resettlement efficiency, effectiveness, impact and sustainability, drawing lessons as a guide to future resettlement planning.

9.6 Conclusions

The assessment on resettlement requirements and preparation of action plan has been provided by the ARUP-CCCC. The proposed acquisition will eventually displace households, commercial premises and common property resources for both titled and non-titled. The RAP covers compensation and assistance for resettlement and rehabilitation of Affected Persons (APs) including alternative sites, where feasible, for relocation of the housing, business structures and Common Property Resources (CPRs). Detailed resettlement action plan including disclosure and public consultation, relocation resettlement and income restoration, implementation arrangements, resettlement and compensation costs and budgets, RAP implementation schedule, grievance redress mechanism as well as monitoring and evaluation have been examined.

10. LAND ACQUISITION PLAN

The construction of this project requires the acquisition of some land, therefore the life of the householders subject to land acquisition will be affected. They'll loss some of their production resources or be forced to relocate to a new land. In order to ensure the smooth completion of this project on schedule, detailed land acquisition plans shall be formulated according to the land acquisition laws and regulations in Bangladesh as below.

10.1 Time Frame for Land Acquisition

The time requirement for payment of CCL may be minimized by concerted efforts at different stages of the land acquisition process. An indicative chart is given below showing tentative time frame of land acquisition.

Sl No.	Steps	1	2	3	4	5	6	7	8	9	10
1	Submission of LA proposal to DC										
2	Feasibility study by DC										
3	Start LA case, issue notice u/s 3										
4	Objection										
5	Send proposal to MOL										
6	Decision of MOL										
7	Invite claim u/s 6										
8	Hearing on claims										
9	Making award										
10	Deposit of Compensation by RB to DC										
11	Payment of compensation										
12	Compensation deemed to have been paid										

Table 10.1-1 Time Frame for Completion of Land Acquisition (in month)

10.2 Land Acquisition

10.2.1 Scope of Work

The scope of work for preparation of the Land Acquisition Plan is elaborated briefly as follows:

The right of way (RoW) of the final tunnel option and access roads has been placed on the mouja maps. The plot numbers falling on the alignment have been

identified and recorded. Either full or part of the areas of lands/plots to be acquired will be computed. The mouja maps have been collected from the Director General, Land Record and Survey (DGLRS) office and DCs Record Room. The Consultant Team has collected mouja maps and draw alignment for preparation of Land Acquisition Plan. During acquisition process the DC will determine the price of acquired land on the basis of market price from the average value of land of the similar description in the vicinity transferred during twelve months preceding the date of publication of notice under section (u/s) 3. The rate will be collected from the office of the Sub-Registrar. The market value of structure will be determined by the Public Works Department (PWD) considering the depreciation cost of the property whereas the cost of trees will be determined by the Department of Forest and that of crops by the Agriculture Extension and Marketing Department. The DC will award an additional sum of 50% of the market value of affected land structure, trees, etc. to the owner of the property. The market value to be determined by the DC usually remains less than the replacement value in almost all cases. Thus for payment of replacement value, Property Valuation Survey is required which will be done by the consultant.

10.2.2 Approach and Methodology

The consultant has collected mouja maps and drawn the alignment/right of way of the tunnel and approach roads by super imposing engineering drawing on the mouza maps. Based on the right of way plot schedule which also mentions the plot numbers, total quantity of land in the plot and total area of proposed land for acquisition in the respective plots have been prepared. The LAP has incorporated land acquisition and resettlement budget. Category wise total quantity of land and the replacement value has been calculated for Resettlement Budget. The replacement value of land, structure and trees has been determined from the property valuation survey data conducted by the consultants.

10.3 Land Acquisition Investigation & Assessment

The following aspects will be included in the detailed Land Acquisition:

10.3.1 Submission of Land Acquisition Plan to Deputy Commissioner

The Requiring Body (RB) is to submit proposal for acquisition of land to the Deputy Commissioner (DC). When the RB is Government, Semi Government or Autonomous organization the proposal for land acquisition should contain:

(i) Administrative approval of the controlling Ministry

(ii) Minimum requirement certificate

(iii) Plot index of proposed land (with name of mouza, JL No., plot no., classification of plot, total quantity of land in the plot, quantity of land proposed for acquisition from the latest survey record).

(iv) Lay-out Plan

(v) Map- the area of proposed land should be demarcated with red ink on the mouja map of the latest survey. Non-acquirable land used by the public for

religious worship, graveyard, cremation ground, should be demarcated with different ink and should be noted with symbol on the map.

(vi) Filled up prescribed form

(vii) No objection Certificate from CDA, RAJUK, RDA, KDA as the case may be.

(viii) Financial approval or approved budget allocation.

(ix) Detailed description of the project.

10.3.2 Land Acquisition by Mouza

According to the drawing of the tunnel alignment and other components including approach road, toll plaza, service area, portal, etc. about 28.96 ha land will be required of which 5.37 ha is private land and remaining are owned by GoB, CUFL, KAFCO and others.

Sl. No.	District	Thana	Mouza	JL No.	No. of Plots	Category wise quantity of land (in ha)				Total
						Khash	Road	Fallow	Private	
1	Chittagong	Anwara	Chaturi	41	53	0.04	0.22	1.09	0.08	1.43
2	Chittagong	Anwara	Belchura	40	46	0.22	0.27	0.93	0.00	1.42
3	Chittagong	Anwara	Boirag	3 (Part 1 & 2)	219	0.56 0.11	0.62 0.09	3.86 1.41	0.62 0.00	7.27
4	Chittagong	Bandar	Bandar	30	79	0.91	0.61	2.38	0.83	4.73
5	Chittagong	Bandar	Rangadia	31	40	4.40	0.48	1.25	0.03	6.16
6	Chittagong	Bandar	Majher Char	33	1	2.93	0.00	0.00	0.00	2.93
7	Chittagong	Bandar	South Potanga	25	54	0.02	1.18	0.00	3.82	5.02
Total					492	9.20	3.47	10.91	5.37	28.96

Table 10.3.2-1 Mouza Wise Area of Private and Public Land to be Acquired

10.3.3 Property Valuation Survey

To determine replacement value of affected property unit rate of each category of losses is required. The consultant collected current market price of land structure, trees and crops from the local people using a structured questionnaire. The land prices were collected for the affected mouzas from local people and averaged to reach a reasonable replacement value. At least 8 persons from different occupational groups such as Imam, Teacher, Potential Seller, Potential Buyer, etc. were interviewed for getting unit rate of land structure and trees. The prices of the affected properties would be collected during detailed design stage for updating

RAP and budget. A detailed budget for land acquisition and is incorporated in the Resettlement Action Plan.

10.3.4 Land Acquisition Budget

The LAP contained land acquisition budget based on the replacement value and quantity of land by category.

The tentative budget for land acquisition as determined during preparation of the RAP is furnished below:

Item No.	Head of compensation	Amount
1	Compensation for land	3,074,018,740
2	Compensation for structure	140,377,030
3	Compensation for Trees	1,207,950
4	Compensation for Crops	1,237,000
	Total BDT	3,216,840,720
	USD	**39,422,068**

Table 10.3.4-1 Tentative Budget for Land Acquisition as Determined during Preparation of the RAP

10.3.5 Disclosure and Public Consultation

For Resettlement planning that includes land acquisition, disclosure and public consultation is considered important. A series of consultation meetings were held in different location at both ends of the tunnel and with different communities and experts/officials for obtaining opinion on the project. The consultants team met the senior officials of Chittagong Development Authority (CDA), Chittagong City Corporation (CCC), Chittagong Port Authority (CPA), Bangladesh Railway, District and Upazila Administration, etc. during preparation of the RAP and LAP. The consultation will be a continuous process and would be held at detailed design and implementation stage of the project. During consultation meeting, goals and objectives of the project have been disclosed to the affected persons and other stakeholders. During detailed design stage the RAP policy including land acquisition requirement and steps adopted for minimizing land acquisition would be disclosed to the affected people and other stakeholders. The following methodology will be followed for disclosure and public consultation;

- Information gathering - from BBA, CDA, CCC and other offices related with the project; and
- Information disclosure - (i) Dialogue with local people, (ii) public meetings, (iii) focused group discussions, (iv) consultation with potential affected persons and (v) personal contact

10.3.6 Compensation Payment Procedure to the Affected Persons

BBA will ensure that the land and other properties (structure, tree, crops and non-structure assets) to be acquired for the project interest will be compensated at their full replacement cost determined by a legally constituted body like the Property Valuation Advisory Committee (PAVC) as per the resettlement Plan. The principle for determining valuation and compensation for assets, incomes and livelihoods targets resettlement assistance for substituting and restoration of loss of income and workdays by the relocated households, especially the vulnerable households. The following steps would be followed during compensation determination and making payment.

a. Upon obtaining administrative approval of the Land Acquisition Proposal from the Ministry of Land (MoL) the DC serves notice under section 3 of the Acquisition and Requisition of the Immovable Property Ordinance 1982 to the recorded owner of the affected property for public appraisal;

b. Acquiring Body (AB) DC and Requiring Body (here BBA) representatives conduct joint verification of the affected property within 3 days of serving notice u/s-3;

c. After that the DC serves notice u/s 6 for entertaining claims from the potential affected persons;

d. On the basis of joint verification survey data DC writes letter to Public Works Department (PWD) with information of affected structures, list of trees to the Forest Department and type of crops to the Agriculture Department for valuation as per government rule;

e. DC also collects recorded land price from the concerned Sub-register's office for 12 months previous from the date of notice under section 3;

f. After receiving rates from the PWD, Forest and Agriculture Department the DC prepares estimate and send it to the RB for placement of fund within 60 days;

g. The DC prepares award for compensation in the name of recorded owner;

h. Upon placement of fund, the DC serves notice u/s 7 to the APs for receiving cash compensation under law (CCL) within 15 days from the date of issuing notice u/s 7;

i. The affected people are noticed to produce record of rights to the property with updated tax receipt of land, declaration on Tk. 150 non-judicial stamp, photograph etc. before Land Acquisition section of DC office;

j. Upon fulfillment of the criteria of the DC office i.e. requisite papers and document the LA section disburse CCL in the office or field level issuing prior notice to the EPs;

k. Local Government Institutions representative identifies the affected people during receiving CCL;

l. As per Land Acquisition Law, DC pays compensation to the legally owner of the properties for land, structure, trees and crops;

m. After receiving CCL from the LA office and obtaining clearance from the Treasury Section of the DC the entitled person (EP) deposits the CCL to his own bank account;

n. One copy of the CCL will be submitted to the IA office for additional payment of compensation as per RAP policy;

o. The IA will create ID number for the CCL holder and prepare EP & EC for payment;

p. The IA will prepare ID card with photograph of the EP;

q. The ID card will be jointly signed by the BBA and IA representative and photograph will be attested by the concerned Ward Councilor;

r. The IA will prepare necessary documents and papers (payment debit voucher, etc.) and submit to BBA along with EP payment list and EP-EC; and

s. The BBA-RU will disburse Account Payee Cheque in public place or office the Ward Councilor.

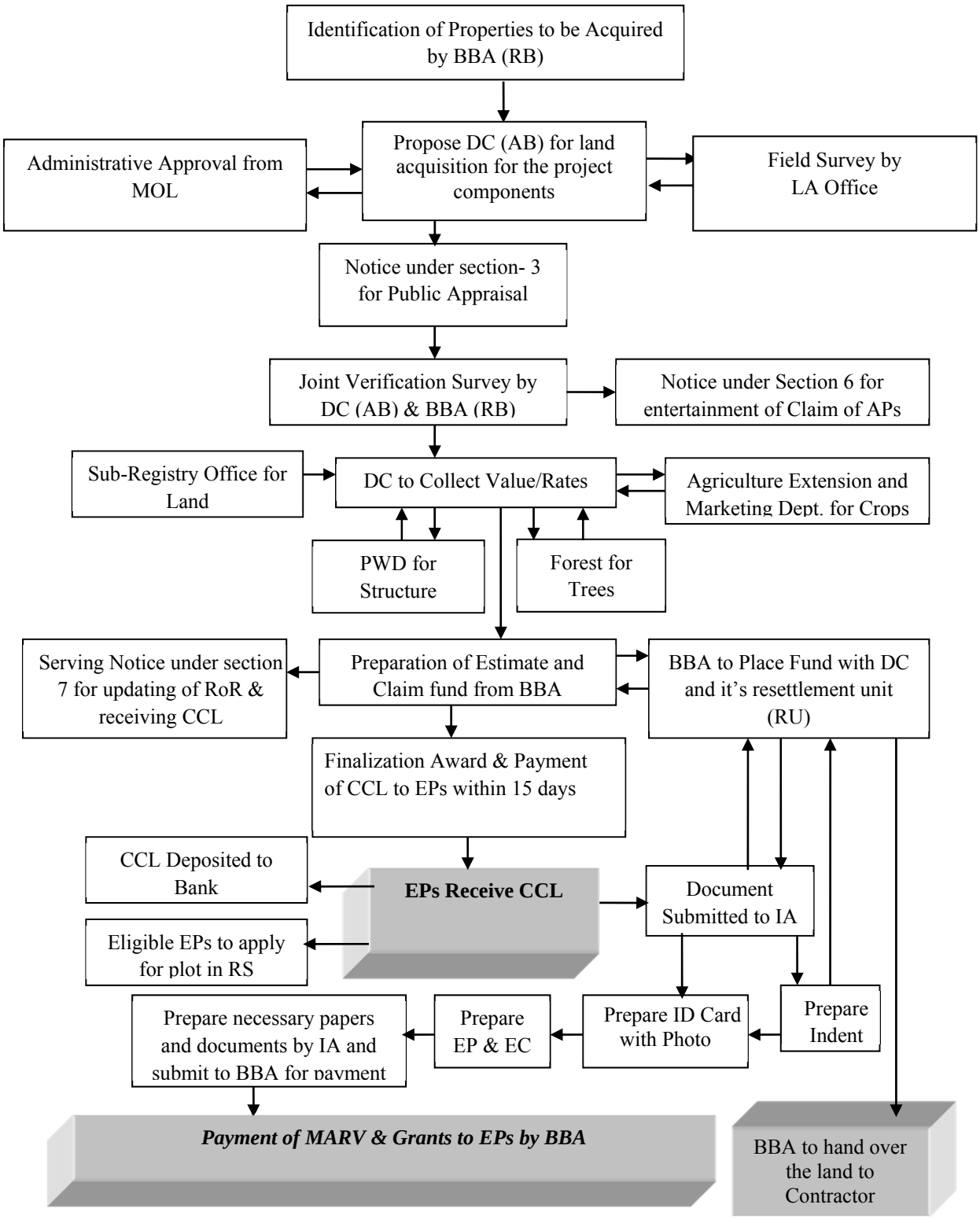


Figure 10.3.6-1 Compensation Mechanism for Legal Title Holder

10.4 Conclusions and Recommendations

The land acquisition plan has been prepared based on the drawing and design provided by the CCCC-ARUP JV. The proposed land acquisition for the project will cause displacement of households, shops and common properties such as

mosque, cremation ground, etc. which is very much sensitive and there is bar in acquisition of such common properties. The project authority should take care of these common properties and take mitigation measures during preparation of the land acquisition proposal as suggested in this document.

11. SOCIO-ECONOMIC IMPACTS ASSESSMENT

11.1 Socio-Economic Profile of East Area of the Karnaphuli River

11.1.1 Overview

The tunnel project will be implemented under the Karnaphuli River connecting Chittagong City to the west with the eastern area along the river in Patiya Upazila (**Figure 9.5.6.1-1Error! Reference source not found.**). The area east of the Karnaphuli River (East Area) is situated outside the boundaries of Chittagong City and is mostly undeveloped and rural in character in part reflecting constrained accessibility and connectivity. The total land area is 50,683 acres comprising Anwara-Karnaphuli (35,198 acres) and Boalkhali-Patiya (15,485 acres), which is equivalent to the one fifth of Chittagong City.

The forecast economic and population growth in Chittagong City will further increase its population density and limit the supply of buildable land especially in the CBD. The proposed tunnel would assist in decentralizing the population and encouraging economic activities away from the urban CBD area to east of the river by improving accessibility and shortening travel times.

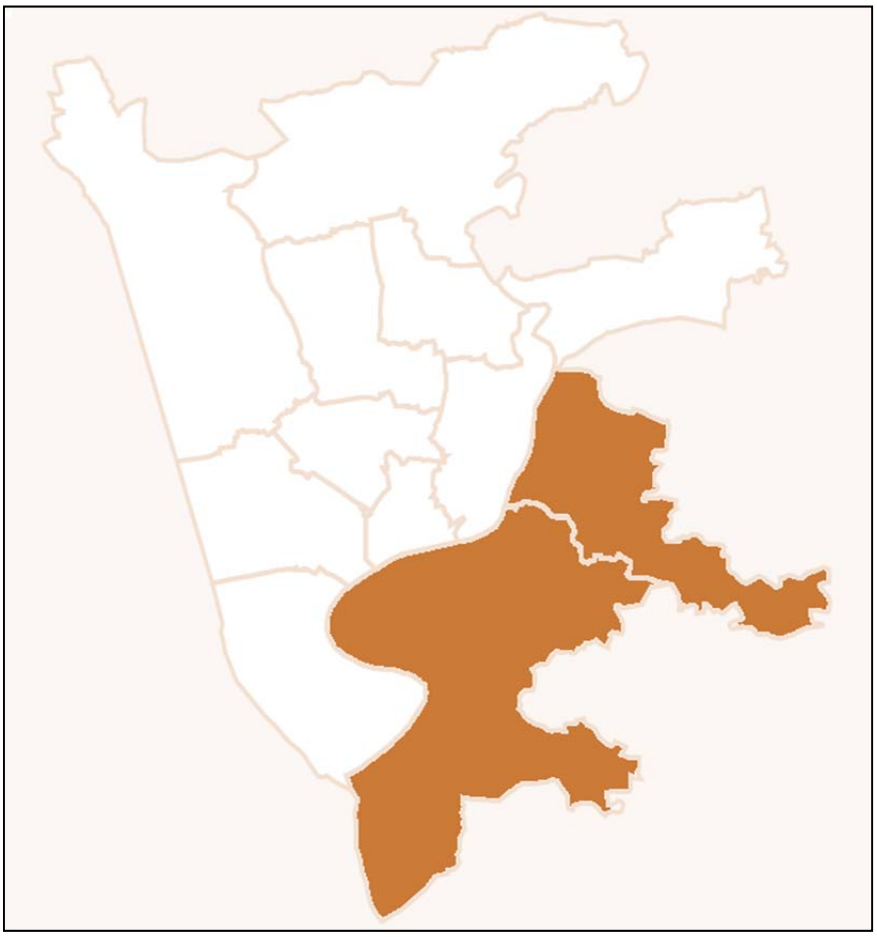


Figure 9.5.6.1-1 East Area along the Karnaphuli River

11.1.2 Population

In 2001, the area east of the Karnaphuli River accommodated almost 400,000 people or 6% of the district population according to the Bangladesh Bureau of Statistics Census 2001. The 2001 population density was 1,943 persons per km^2, much lower than Chittagong City of 5,761 persons per km^2.

Anware – Karnaphuli District where the proposed tunnel will connect accounted for over 70% of the land and 60% of the population (**Table 9.5.6.1-1**).

District	Area (Acre)	2001 Population	Population Density (Persons/km^2)
Anwara-Karnaphuli	35,198	239,756	1,683
Boalkhali-Patiya	15,485	158,759	2,533
Total	**50,683**	**398,515**	**1,943**

Table 9.5.6.1-1 Population in East Area

Source: "Preparation of Detailed Area Plan (DAP) for Chittagong Metropolitan Master Plan (CMMP)" published by Chittagong Development Authority in 2008

The population east of the Karnaphuli River is anticipated to grow at 1.7% from around 400,000 people in 2001 to 504,000 people in 2015 equating to a population density of 2,456 persons per km^2.

District	2015 Population	Population Density (Persons/km^2)
Anwara-Karnaphuli	291,907	2,049
Boalkhali-Patiya	211,907	3,382
Total	**503,814**	**2,456**

Table 9.5.6.1-2 East Area Population Projections 2015

Source: Detailed Area Plan for Chittagong Metropolitan Master Plan conducted by Chittagong Development Authority, 2008

11.1.3 Land Use Distribution

According to the land use survey[9], the current dominant land use east of the Karnaphuli River is agriculture and fisheries and residential facilities, occupying almost 70% of the total land area. The manufacturing and processing sector, which provides significant economic contribution accounts for less than 2% of the land. **Table 9.5.6.1-1** presents the current land use distribution in the area east of the Karnaphuli River.

Land Use Type	Distribution %
Agriculture and Fisheries	47.0%
Residential	10.7%
Transport & Community	2.7%

[9] The Land Use Survey was conducted to provide the land use information for supporting the Detailed Area Plan for Chittagong Metropolitan Master Plan

Land Use Type	Distribution %
Manufacturing & Processing	1.7%
Restricted	1.6%
Commercial Activity	1.0%
Water Body	23.1%
Coastal Char & Sea Beach	3.2%
Hilly Land	3.1%
Vacant Land	5.0%
Other	0.8%
Total	**100.0%**

Table 9.5.6.1-1 Land Use Distribution East of the Karnaphuli River

Source: DPZ 11-12, "Preparation of Detailed Area Plan (DAP) for Chittagong Metropolitan Master Plan (CMMP)" 2008 published by Chittagong Development Authority

11.1.4 Economic Conditions

Due to the constrained accessibility and connectivity with Chittagong City to the west, the area east of the Karnaphuli River is mostly undeveloped and rural in character. In addition to some manufacturing facilities, a small amount of economic activities are clustered adjacent to the two existing bridges.

The Socio-economic Survey Report of DAP published in 2007 indicates the economy east of the Karnaphuli River is mainly dependent on the agriculture, fisheries and manufacturing industries. The agricultural sector currently plays an important role and occupies approximately 47% of the total land area.

The main industrial activities are mostly located on the east bank of the Anwara-Karnaphuli District and include the Karnaphuli Fertilizer Company Limited (KAFCO) and Chittagong Urea Fertilizer Limited (CUFO).

11.1.5 Transport and Connection

Connectivity between Chittagong City and east of the Karnaphuli River is mainly via two existing bridges. The proposed industrial development in the East Area adjacent to the two existing bridges will significantly increase the traffic demand between west and east. Both bridges are anticipated to be insufficient to accommodate the increased traffic demand which will limit the development potential in the East Area.

11.1.6 Proposed Development

The area east of the Karnaphuli River particularly Anwara-Karnaphuli District, is proposed for industrial and agricultural development with supporting commercial and residential facilities. Industrial and agricultural related uses are proposed to utilize almost half of the total land area (**Table 9.5.6.1-1**).

Land Use Type	Distribution %
Industrial	24%
Agricultural land	21%
Residential & Ancillary	20%
Mixed Use	8%
Recreation, Leisure and Open Space	3%
River	8%
Riverside Afforestation	4%
Urban Deferred Area	10%
Total	**100%**

Table 9.5.6.1-1 Proposed Land Use Distribution East of the Karnaphuli River

Source: DPZ 11-12, "Preparation of Detailed Area Plan (DAP) for Chittagong Metropolitan Master Plan (CMMP)" 2008 published by Chittagong Development Authority

11.1.6.1 Growth Centres

Growth centres are intended to stimulate economic activities and comprise commercial and residential areas, small scale light industry and other urban amenities. There are thirteen identified growth centres in Chittagong City of which eight are defined as a 1st category growth centre with five of them located east of the Karnaphuli River. Transport infrastructure including roads and parking facilities will be upgraded to support the growth centre.

11.1.6.2 Transport Infrastructure

In order to enhance and encourage industrial development, the Long Term Development Strategy for traffic and transport proposed widening three major roads to improve traffic movements between Chittagong City and east of the Karnaphuli River. In addition, a large number of secondary roads will be upgraded and developed on an incremental basis such as the widening road between Chowmohoni Bazaar Moore to KAFCO Moore.

11.1.6.3 Manufacturing Sector

The CDA reported that there is a shortfall of buildable land and thus the majority of the eastern side adjacent to the Karnaphuli River is zoned for port related industrial use with the provision for supporting facilities. Almost 25% of land is reserved for industry development of which over 70% is located in the Amwara-Karnaphuli District where the proposed tunnel will connect.

11.1.6.4 Recreational Development

According to the Detailed Area Plan (DAP) for Chittagong Metropolitan Master Plan, about 1,700 acres of land in Parkir Char and South Patenga are proposed for coastal related recreational activity. This is intended to improve the tourist facilities in the Chittagong City and Bangladesh as a whole.

11.2 Social Impact Assessment

11.2.1 Introduction

Construction of the proposed tunnel would stimulate a range of positive impacts to the population of Chittagong City and the East Area. These include better accessibility and mobility for people to access employment, recreation, education and health facilities. Improving the livelihoods of the population has real benefits for the nation as whole.

Tunnel Construction is not without negative impacts and the most significant of these will be the impacts to the private landowners whose properties will be affected by the alignment.

The anticipated impacts are described further in the following section.

11.2.2 Impact on GDP

In terms of direct impact on GDP – we have found that the project has only a slight impact on economic growth. We assumed a base case of 6% GDP growth, therefore the project would increase this amount by 0.166% that is GDP would be 6.166% with the project over the 50 years of the project.

11.2.3 Employment Impact

In terms of the impact on unemployment, we have assumed a 5% unemployment rate, which is consistent with the publicly available data but probably masks a number of structural inefficiencies. Over the project construction phase this would fall to about 4.9% with approximately 241,000 jobs created over this period. Whereas the impact is considerably lower in the out years of the project life with an average of 17,900 jobs being created each year. In the context of the unemployment rate this would mean only a slight reduction to 4.98% from 5%.

11.2.4 Local Employment Impact

While the reduction in the overall unemployment rate is relatively minor, the localised impacts of the tunnel are predictably extremely high. As outlined below there are a number of jobs created in the construction years of the project, as well as a number of new jobs created as direct consequence of the tunnel's operation.

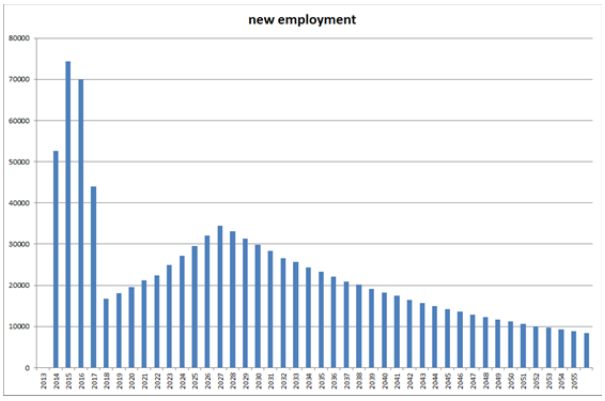


Figure 11.2.4-1 New Employment

11.2.5 Localised Impact on the Unemployment Rate

These jobs translate into a direct impact on unemployment in the local area. As can be seen below there are three pronounced impacts of the tunnels construction and operation. The first is the construction phase where there will be more jobs than the local market is able to provide. This will obviously have a major impact on the local unemployment rate, however, it is unlikely that unemployment rate will go negative. Rather, it is expected that the jobs created over this phase will be awarded to people outside of the local area. This result is driven by a combination of the number of jobs and the skills required to complete the construction of the tunnel. The second stage will see the direct benefit of the tunnel on the local area. Holding all other things equal within the economy, the direct impact of the tunnel can be seen after the construction phase is completed and local economic activity yields almost full employment in the local area. The third and final stage will be the return of an economic equilibrium whereby the local jobs market returns to the national average.

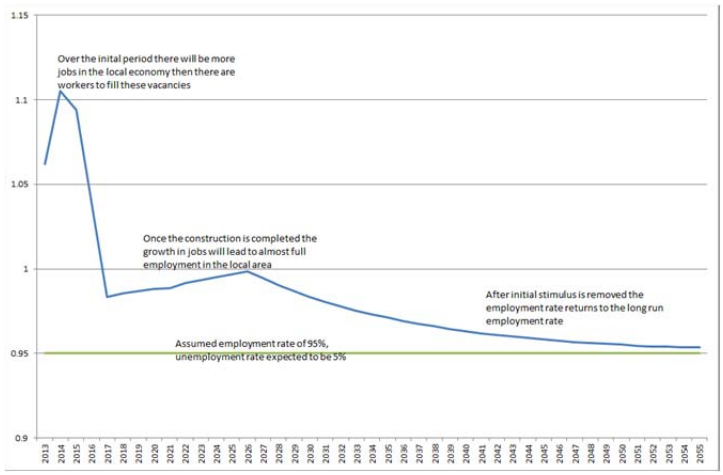


Figure 11.2.5-1 Localised Impact on the Unemployment Rate

11.2.6 Poverty Reduction

The impact on poverty reduction is an interesting one and one that is very vexed in terms of the definition of the poverty and other factors. However, since 2000 the poverty rate as defined by Bureau of Statistics of Bangladesh as fallen from 49% to 31.5%. Notwithstanding the various methodological issues this decline has been driven by an average economic growth in GDP of 6% per annum over this same period. To estimate the reduction in poverty due to the construction of this tunnel we have assumed that this relationship will continue, as such the higher growth rate of 6.166% will have a positive impact on the number of people defined as living in poverty.

The figure below outlines the impact in the poverty rates with the tunnel and without the tunnel. The assumed GDP growth in the without tunnel scenario is 6 per cent per annum.

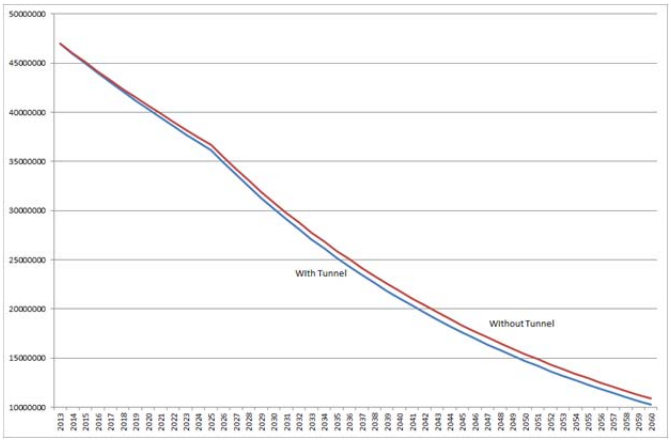


Figure 11.2.6-1 Impact on Poverty Reduction

Therefore, on the available data the reduction in poverty directly related to the project is in the order of 700,000 over the life of the project. In the next 10 years that number would be approximately 400,000. Over the life of the project approximately 15,000 people per annum will be defined as being out of poverty, as defined by the Bangladesh Bureau of Statistics.

11.2.7 Population

Construction of the proposed tunnel is anticipated to have a positive impact on the population of the East Area.

Based on the key findings of the meeting with the CDA, it is plausible to assume that a proportion of the population would reside in the East Area while commuting to Chittagong City for work and study. Over time, it is expected the presence of the tunnel will further entice migration into the East Area due to the substantial improvements in accessibility it provides.

The area west along the Karnaphuli River covering the CBD and surrounding areas has a substantially higher population density than other areas in the city and Bangladesh as a whole (**Table 11.2.7-1**). The population density in the west area along the river (DPZ 1 – 5 in the "Preparation of Detailed Area Plan (DAP) for CMMP") will reach 18,805 persons per km^2 in 2015, almost eight times higher than the East Area. The proposed tunnel is intended to decentralize the population from west to east through increased accessibility and shortened travel times.

Area	2001 Population Density (Persons/km^2)	2015 Population Density (Persons/km^2)
West Side Area along the Karnaphuli River (DPZ 1- 5)	11,039	18,805
Anwara-Karnaphuli (DPZ 12)	1,683	2,049
Boalkhali-Patiya (DPZ 11)	2,533	3,382

Table 11.2.7-1 Population Density with the Tunnel

Source: Estimated based on the "Preparation of Detailed Area Plan (DAP) for Chittagong Metropolitan Master Plan (CMMP)" 2008 published by Chittagong Development Authority

11.2.8 Mobility and Accessibility

One of the most significant benefits of the proposed tunnel will be enhanced mobility and accessibility. The tunnel will allow the local population in the East Area to move quickly to Chittagong City for work, study and recreational activities. According to the Detailed Area Plan for Chittagong Metropolitan Master Plan, the majority of the East Area is zoned industrial and agricultural uses with provisions for supporting commercial and residential facilities. The industrial zone identified in the East Area accounts for over 50% of total industrial land in Chittagong City and its surrounding areas[10].

Shah Amanat Bridge is currently able to handle traffic demand in the CBD and surrounding areas. However the rapid population and economic growth in the city will significantly increase traffic demand and the bridge may not be able to handle the additional demand after 10 years. The proposed tunnel will divert vehicles from the CBD and provide additional capacity to the transportation network.

11.2.9 Land Acquisition

Substantial land acquisition is anticipated and compensation is estimated at US$39.4 million.

11.3 Economic Impact Assessment

11.3.1 Introduction

Cost and benefit components over the entire assessment period are identified and entered at the relevant time period in a discounted cash flow model to calculate Present Value (PV) costs and benefits. The total PV cost and benefits are compared against each other and the difference represents the Net Present Value (NPV) of the project.

11.3.2 The With and Without Project Cases

11.3.2.1 With Project Case

The With Project Case assumes the proposed tunnel is built which results in greater (additional) economic and social development in Chittagong City and Bangladesh as a whole.

11.3.2.2 Without Project Case

The Without Project Case assumes the proposed tunnel is not built and planned strategies and infrastructure projects and basic economic development will go ahead as forecast under the Detailed Area Plan prepared by Chittagong Development Authority.

[10] The Chittagong City and its surrounding areas comprise Chittagong City, East Area and other surrounding areas.

11.3.3 Cost Summary

A summary of capital and operational cost expenditure and residual value are shown below (**Table 11.3.2.2-1**).

Item	Proposed Tunnel
Capital Costs (2013 – 2016)	US$ 522.3
Operational Costs / per annum (2017 – 2062)	US$ 3.9
Replacement Costs per 5 years	US$ 1.9
Residual Value [a]	US$ 282.1

Table 11.3.2.2-1 Summary of Costs (US$ Million, 2012 prices)

Note: [a] Accounted as a benefit

11.3.4 Economic Benefits

There are four major types of economic activities arising from development of the tunnel that would generate value added and employment opportunities in Chittagong during the operation stage.

11.3.4.1 Core Staff for Management and Operation of the Tunnel

During the operation phase, direct economic benefit arises from tunnel management and operational services provided by core staff. A total of 250 staff is expected to be required during the operational stage and all of them are anticipated to be locally hired Bangladeshis. The economic benefit can be estimated based on the projected number of employees and the value added per person engaged. The payroll per staff engaged to manage and operate the proposed tunnel could roughly represent their value added contribution.

The total direct value added contribution to the Bangladesh economy is estimated at Tk 36 million or US$ 0.44 million per annum during the operation phase. The estimated economic benefit is presented in **Table 11.3.4.1-1**.

Item	Assumptions
Estimated Number of Staff	250
% Local Labour	100%
Wage per month per worker (taka)	12,000
Total Value Added (taka million)	**Tk 36 million**
Total Value Added (US$ million)	**US$ 0.44 million**

Table 11.3.4.1-1 Value Added Contributions during Operation (per Annum)

11.3.4.2 Traffic Related Economic Benefits

The daily numbers of vehicles were converted to annual numbers using an annualisation conversion factor of 365. [11] The assessment of the tunnel performance in handling the predicated vehicles has been presented in the Traffic Survey Analysis and Forecast Reports prepared by DevConsultants Ltd and a summary is provided in **Table 11.3.4.2-1**.

There are forecast to be some 6.3 million vehicles travelling through the tunnel per annum in 2017, rising to 13.9 million in 2030, 32.9 million in 2050 and 50.5 million in 2062. Of the total number of vehicles using the tunnel, trucks account for almost 50%. The traffic forecasts have assumed that the Deep Sea Port development in Sonadia Island will encourage trucks to use the Dhaka-Chittagong Highway to transport cargo to other parts of the country. In addition, the proposed tunnel will serve the proposed industrial zone located east of the Karnaphuli River and will divert truck traffic from the two existing two bridges.

Item	2017	2020	2030	2040	2050	2062
Heavy Truck Trailer Container	1.2	1.4	2.6	4.2	6.1	9.4
Medium Truck	1.1	1.3	2.3	3.8	5.5	8.5
Small Truck Pickup Small Van	0.9	1.1	1.9	3.2	4.6	7.1
Large Bus	0.5	0.6	1.1	1.8	2.6	4.0
Mini Bus	0.8	0.9	1.7	2.7	3.9	6.1
Microbus	1.2	1.4	2.6	4.2	6.1	9.4
Utility	0.1	0.1	0.2	0.3	0.5	0.7
Car, Jeep/ Van	0.7	0.8	1.5	2.4	3.5	5.4
Total	**6.3**	**7.6**	**13.9**	**22.6**	**32.9**	**50.5**

Table 11.3.4.2-1 Number of Vehicles per Annum (million)

Source: DevConsultants

11.3.4.2.1 Time Saving

The generalized time savings are used to value the economic benefits of improved transport access for vehicles. The provision of new tunnel infrastructure can allow passengers to benefit from a shorter journey which is reflected in travel time savings. The average time saving per vehicle per option is shown below.

[11] Source: DevConsultants

Option	2017	2020	2030	2040	2050	2062
Time Savings	20	19	19	19	19	19

Table 11.3.4.2.1-1 Average Time Saving per Vehicle (Minutes)

Notes: The Time Savings after 2036 are assumed to be held constant being conservative

Time savings are converted into monetary values by multiplying the respective time savings in minutes for each vehicle group by that group's value of time (VOT).

The VOT for each vehicle group is based on the Feasibility Study of the Third Karnaphuli Bridge and inflated to current prices. The annual time saving is shown below in **Table 11.3.4.2.1-3**.

Vehicle Type	Tk per hour
Heavy Truck Trailer Container	256.2
Medium Truck	192.1
Small Truck Pickup Small Van	128.1
Large Bus	1,721.8
Mini Bus	938.6
Microbus	938.6
Utility	361.2
Car, Jeep/ Van	361.2

Table 11.3.4.2.1-2 Value of Time per Hour (Tk, 2012 Prices)

Source: Estimates based on Feasibility Study of the Third Karnaphuli Bridge, Ministry of Economic Affairs, December 2001 and inflated to current prices

Option	2017	2020	2030	2040	2050	2062
Annual Time Savings	14.7	16.9	30.4	50.4	73.1	112.5

Table 11.3.4.2.1-3 Annual Time Savings (US$ million, 2012 prices)

Notes: The Time Savings after 2039 are assumed to be held constant being conservative

11.3.4.3 Savings in Vehicle Operational Costs

Vehicle operational cost savings accrue from a reduction in distances travelled. The cost savings is estimated based on the marginal change in distances travelled per vehicle type and operation and maintenance cost per mile per vehicle type. The Vehicle Operational Cost per vehicle type per mile is shown below.

Vehicle Type	Tk per mile
Heavy Truck Trailer Container	31.1
Medium Truck	23.3
Small Truck Pickup Small Van	15.5
Large Bus	31.1
Mini Bus	15.5
Microbus	15.5
Utility	5.1
Car, Jeep/ Van	5.1

Table 11.3.4.3-1 Vehicle Operational Cost per Mile (Tk, 2012 Prices)

Source: Estimates based on Feasibility Study of the Third Karnaphuli Bridge, Ministry of Economic Affairs, December 2001 and inflated to current prices

According to the latest Traffic Survey Analysis and Forecast, the average distance saving per vehicle per option is estimated at negative 1.1 miles.[12]

The annual vehicle operational cost saving is shown below.

Option	2017	2020	2030	2040	2050	2062
Annual Vehicle Operational Cost	-2.2	-2.2	-4.4	-5.8	-8.4	-12.9

Table 11.3.4.3-2 Annual Vehicle Operational Cost (US$ million, 2012 prices)

Notes: Negative indicates an increase in travel distance

11.3.4.4 Value Added Contributions from Manufacturing Sector

Construction of the proposed tunnel is anticipated to improve the utilization rate of industrial land east of the Karnaphuli River due to improved connectivity with

[12] Negative indicates an increase in travel distance

Chittagong City, better mobility of labour, and the ability to move raw materials and completed products easily via the airport and port.

Based on the current land use distribution, the west side of Karnaphuli River comprises the airport, port and CBD while large areas to the east are mostly undeveloped.

Existing industrial areas are distributed across Chittagong City and surrounding areas amounting to a total land area of approximately 6,055 acres. More than 85% are located west of the river of which around 3,000 acres are clustered near the airport and the port. The area east of the Karnaphuli River accounts for around 15% of the total industrial land which may reflect constrained connectivity (**Table 11.3.4.4-1**).

	Area (Acre)	**%**
Western side of the Karnaphuli River (Chittagong City)	5,188	86%
East side of the Karnaphuli River	867	14%
Total	**6,055**	**100%**

Table 11.3.4.4-1 Existing Industrial Area Distribution

Source: Detailed Area Plan for Chittagong Metropolitan Master Plan conducted by Chittagong Development Authority, 2008

The area east of the Karnaphuli River is proposed as an industrial zone development comprising 12,324 acres. Almost 9,000 acres (over 70%) are located in the Anwara-Karnaphuli where the proposed tunnel will connect. [13]

District	**Existing Area (Acre)**	**Planned Area (Acre)**
Anwara-Karnaphuli	801	8,981
Boalkhali-Patiya	66	3,344
Total	**867**	**12,324**

Table 11.3.4.4-2 Proposed Industrial Areas East of the Karnaphuli River

Source: Detailed Area Plan for Chittagong Metropolitan Master Plan conducted by Chittagong Development Authority, 2008

Construction of the proposed tunnel is anticipated to improve the utilization rate of industrial land in Anwara-Karnaphuli area due to enhanced connectivity with urban areas in Chittagong City.

The total value added contribution of industrial land in Chittagong District during 2001 to 2010 was on average estimated at US$ 0.33 million per acre in 2012 prices.

It has been assumed that the area within a 3 km radius around the proposed tunnel will be developed as a result of improved connectivity and accessibility. The total industrial land area is approximately 2,083 acres. In the assessment, it has been

[13] Detailed Area Plan for Chittagong Metropolitan Master Plan conducted by the Chittagong Development Authority in 2008

conservatively assumed that an additional 50% of industrial land will be utilised over the 50 year assessment period. This equates to an increase from 801 acres currently utilised to 1,202 acres which accounts for around 58% of the total zoned industrial area of 2,083 acres. It is also assumed that there is a 10 year ramp up period after the tunnel first opens before the total 50% additional area is fully utilised.

Option	2017	2020	2030	2040
Manufacturing Sector Value Added	33.2	52.7	132.7	132.7

Table 11.3.4.4-3 Annual Additional Value Added from Manufacturing Sector per Option (US$ million, 2012 prices)

Notes: Based on the ramp up period of 10 years from 25% in year 1 to full utilization in year 10.

11.3.5 Economic Evaluation

11.3.5.1 Tangible Economic Benefits

Based on an assessment period of 50 years covering construction and operational periods and assuming a real discount rate of 5%, the results of the economic analysis are shown in **Table 11.3.5.1-1**. The results show that the project is also economically viable under higher real discount rates of 9% and 12%.

Items	Undiscounted	Discounted @ 5%	Discounted @ 9%	Discounted @ 12%
Capital Costs	-522.3	-462.9	-422.7	-396.1
Operational Costs	-179.5	-57.4	-30.1	-20.6
Replacement Costs	-17.1	-5.0	-2.4	-1.6
Total Costs	***-718.9***	***-525.3***	***-455.3***	***-418.2***
Residual Value	282.1	24.6	3.8	1.0
Travel Time Savings	2,163.9	477.3	194.5	115.1
Manufacturing Sector Additional Value Added	5,506.7	1,545.5	719.5	450.0
Tunnel Operational Benefits	20.3	6.5	3.4	2.3

Items	Undiscounted	Discounted @ 5%	Discounted @ 9%	Discounted @ 12%
Total Benefits	***7,972.9***	***2,053.8***	***921.2***	***568.4***
NPV	**7,254.0**	**1,528.5**	**465.9**	**150.2**
Economic Internal Rate of Return	**N/A**	**14.7%**	**14.7%**	**14.7%**
Benefit- Cost Ratio	**N/A**	**4.1**	**2.0**	**1.4**

Table 11.3.5.1-1 Economic Analysis Summary Results (US$ Million, 2012 prices)

Notes: Based on 50 year assessment period

11.3.5.2 Intangible Economic Benefits

In addition to the quantified economic benefits above, there are also other intangible economic benefits which are equally important.

11.3.5.2.1 Better Social and Economic Integration in Chittagong District

Due to the constrained accessibility and connectivity, the East Area is mostly undeveloped and vastly rural in character. The rapid population and economic growth in the Chittagong City will significantly increase the demand for buildable land.

According to the Detailed Area Plan for Chittagong Metropolitan Master Plan, Chittagong City is mainly zoned into residential and commercial use. The East Area along the river is zoned into industrial use with the provision for supporting facilities.

The proposed tunnel will increase connectivity and accessibility between the port, airport and east bank of the Anwara-Karnaphuli area. This will increase the utilization of the industrial zone and other commercial areas and stimulate the economic development in the East Area. In addition, the proposed tunnel could decentralize the population and economic activities from urban area in Chittagong City to the East Area through improving the accessibility and shortening the travel times.

11.3.5.2.2 Deep Sea Port Development

Along with the rapid economic growth and diversification away from agriculture to industrial development, the existing port facilities in Bangladesh are not sufficient to accommodate increasing demand. As a result the Government is considering developing a new deep sea port in Sonadia Island.

The new deep sea port developed in Sonadia Island would generate traffic that will use the Dhaka-Chittagong Highway to transport cargo to other parts of

Bangladesh. According to the Feasibility Study, the new deep sea port is expected to handle over 320 million tonnes per annum in 2055. The proposed tunnel is intended to provide direct connectivity with the Deep Sea Port and cater to the additional traffic. This would also divert traffic away from the CBD

11.3.5.2.3 Tourism

According to the latest development plan, the land in Parkir Char (east side along the river) and South Patenga (west side along the river) are proposed for recreational activities.

Approximately 1,700 acres of land in the Parkir Char area are proposed to be developed as coastal related tourist facilities. The existing Patenga sea beach will be upgraded and new sites will be developed. An area west of the coast may be reserved for camping, picnic, and annual sporting and other community events and an area east of the Patenga road may be used for an amusement park. In addition, an area between the airport and industry is proposed to be turned into a water based tourist site, and a 1 km harbourfront public promenade will be developed from an airport to naval installation.

The proposed tunnel provides the greatest connectivity between these two areas and creates synergies between existing and proposed tourism assets and the port and airport in Chittagong city.

11.3.5.2.4 Emergency Response

The present transportation connecting the airport and surrounding areas to western Patiya area is inconvenient. The only options are to travel by either boat or land across two existing bridges. The journey time via land is long during peak periods due to traffic congestion in the CBD and travelling by boat is limited by the number of persons and volume of goods that can be carried. The proposed tunnel could allow faster response and deployment during emergencies in the East Area.

11.4 Summary and Conclusions

Chittagong City is the main metropolitan area in south-eastern Bangladesh and is the capital of Chittagong District. It has a population of some 5.7 million people and is the second largest city in the country. It is built along the Karnaphuli River and contains an international airport and Bangladesh's busiest port. The tunnel project will be implemented under the Karnaphuli River and connect Chittagong City with planned development areas to the east. A range of social and economic benefits are expected to result from the tunnel including:

- Better connectivity with the proposed industrial developments located east of the Karnaphuli River and the existing port, airport and CBD to the west;
- Reduced congestion in the CBD and on existing bridges;
- Shorter journey times and travel time savings;
- Better utilisation of land east of the river for manufacturing generating additional value added contributions to the national economy as a result of better labour mobility, and the ability to efficiently move raw materials and completed products via the airport and port;

- Direct connectivity with the New Deep Sea Port to be developed in Sonadia Island and catering to the additional traffic;
- Creation of synergies between the port and airport and existing and proposed tourism assets in Parkir Char east along the river and South Patenga west along the river;
- Improved emergency response in the East Area and the western sections of Patiya.

The results of the economic analysis indicate that the project is economically viable under various real discount rates and a summary is provided in the following table.

Items	Undiscounted	Discounted @ 5%	Discounted @ 9%	Discounted @ 12%
NPV	**7,254.0**	**1,528.5**	**465.9**	**150.2**
Economic Internal Rate of Return	**N/A**	**14.7%**	**14.7%**	**14.7%**
Benefit- Cost Ratio	**N/A**	**4.1**	**2.0**	**1.4**

Table 11.4-1 Economic Analysis Summary Results (US$ Million)

Notes: Based on 50 year assessment period

12. FINANCIAL ASSESSMENT AND OPTIMUM TOLL RATE DETERMINATION

12.1 Introduction

12.1.1 Objectives

The objectives are to assess the financial aspects of the proposed tunnel.

12.1.2 Limitations

Current accepted professional practices and procedures were used in the development of this report. However, as with any forecast, there may be differences between forecasted and actual results. The report contains reasonable assumptions, estimates, and projections that may be indicative of future values or events. However future developments cannot be predicted with certainty and this will affect the estimates or projections expressed in this report. Consequently the Consultant Team specifically does not guarantee or warrant any estimate or projections contained in this report.

This document is intended only for the information of the Bangladesh Bridge Authority. It is not intended for and should not be relied upon by any third party, and no responsibility is undertaken to any third party. Our findings are based on limited technical, financial, and commercial data.

The Consultant Team has relied upon assumptions and estimates and is not aware of any facts that would make such information misleading. We envisage that if the project is to be taken forward, further validation of our findings will be undertaken as part of the procurement process.

We must emphasise that the realisation of any prospective financial information set out is dependent on the continuing validity of the assumptions on which it is based. We accept no responsibility for the realisation of the prospective financial information. Actual results are likely to be different from those shown in the prospective financial information because events and circumstances frequently do not occur as expected, and the differences may be material.

12.2 Financial Analysis Assumptions

12.2.1 Introduction

The financial analysis attempts to ascertain the extent to which the investment can be recovered through toll revenue and the gap, if any, to be funded through alternative revenue sources. This covers aspects like financing through debt and equity, loan repayment, debt servicing, taxation, depreciation, etc.

The viability of the project is evaluated on the basis of Project Net Present Value (NPV) and Financial Internal Rate of Return (FIRR) computations.

12.2.2 Overview of Approach

Costs and revenues have been evaluated over a 34 year assessment period from 2013 to 2046. The approach includes:

- Capital costs spread across a 4 year construction period from 2013 to 2016
- Annual operational and maintenance costs over a 30 year operational period from 2017 to 2046
- Financial costs based on the assumed financing structure
- Annual toll revenues based on forecast traffic over a 30 year operational period

The annual cash flows are entered at the appropriate period within a Discounted Cash Flow Model and converted to present day values to estimate the NPV for the project.

12.2.3 Key Assumptions

The main key assumptions adopted for the financial analysis includes , Assessment Period, Discount Rate, Inflation, Borrowing Costs and Corporation Tax etc.

12.2.4 Costs

A summary of capital and operational costs are shown below. Capital and operational costs are inflated at the assumed 20.1% and 6.4% per annum inflation rate respectively.

Item	US$ Million
Capital Costs (2013-2016)	522.3
Operational Costs per annum (2017-2046)	3.9
Replacement Costs (every 5 years)	1.9

Table 12.2.4-1 Summary of Costs (US$ Million, 2012 Prices)

12.2.5 Revenues

The total toll revenues have been estimated by multiplying the number of vehicles by the assumed toll rates. The annual revenues inclusive of inflation for Alignment C are shown below.

Item	2017	2020	2030	2040	2046
Alignment C	25.7	36.8	125.5	381.5	692.4

Table 12.2.5-1 Toll Revenues per Annum (US$ Million)

Note: Includes inflation

12.2.5.1 Scenarios for Financing Structures

Three financing structures have been assumed for the project. Option 1 is based on 100% of the financing being provided by the government and is equivalent to the public sector comparator. Options 2 and 3 are partial and full debt models. The scenarios are summarised in **Table 12.2.5.1-1**.

Scenario	Description/Assumption
Option 1 - 100% Government Financed (equivalent to the Public Sector Comparator)	The Government subsidizes all costs through a cash payment and will not seek alternative funding mechanisms such as loan (debt) and/or equity.
Option 2 - 50% & 50% Government Financed	The Government directly subsidizes half of all costs through a cash payment while the remainder is funded through a loan (debt).
Option 3 - 100% Loan	The Government funds all costs through a loan (debt).

Table 12.2.5.1-1 Toll Assumed Financing Structures

Note: Government financed means a cash injection by the Government exclusive of borrowing costs.

12.3 Financial Analysis Results

12.3.1 Financial Viability Analysis

12.3.2 Key Findings

The findings of the financial analysis indicate that under the assumptions adopted, the tunnel, inclusive of toll revenues is not financially viable without government support. The analysis indicates the tunnel would require around US$275 million of funding in NPV terms (Option 1). The findings also indicate that depending on the financing structure, the funding gap ranges from US$305 million to US$341 million (**Table 12.3.2-1**).

Item	Option 1	Option 2	Option 3
Funding Scenario	100% Government Financed	50% Loan [a] & 50% Government Financed	100% Loan [a]
NPV (US$ million)	-274.6	-305.1	-341.0
FIRR	8.4%	7.3%	6.0%

Table 12.3.2-1 Financial Analysis Summary Results for Alignment C

Notes: [a] Interest Rate of 13%

12.3.3 Cash Flow Analysis

The cash flows of the three different financing scenarios are presented in the following sections.

12.3.3.1 Option 1 – 100% Government Financed

The funding gap under Option 1 is approximately US$275 million in NPV terms for the project (**Table 12.3.3.1-1**). The cash flow under the assumption that the funding gap is met by a government subsidy is shown in **Figure 12.3.3.1-1** Error! Reference source not found..

The significant funding gap clearly shows that the toll revenue is insufficient to finance the project on a commercial basis. The costs and revenues have been discounted at a nominal rate of 12%.

Summary	Alignment C	
	Undiscounted	PV@12% Nominal Discount Rate
Revenues	6,624.3	469.4
Operational and Replacement Costs	-485.8	-51.3
Capital Costs	-840.0	-623.4
Financial Costs	0.0	0.0
Tax	-1,460.9	-69.3
NPV	**3,837.6**	**-274.6**
FIRR		**8.4%**

Table 12.3.3.1-1 Financial Summary for Option 1 (US$ Million)

Notes: Undiscounted refers to the sum of the annual undiscounted value inclusive of inflation over the 35 years assessment period

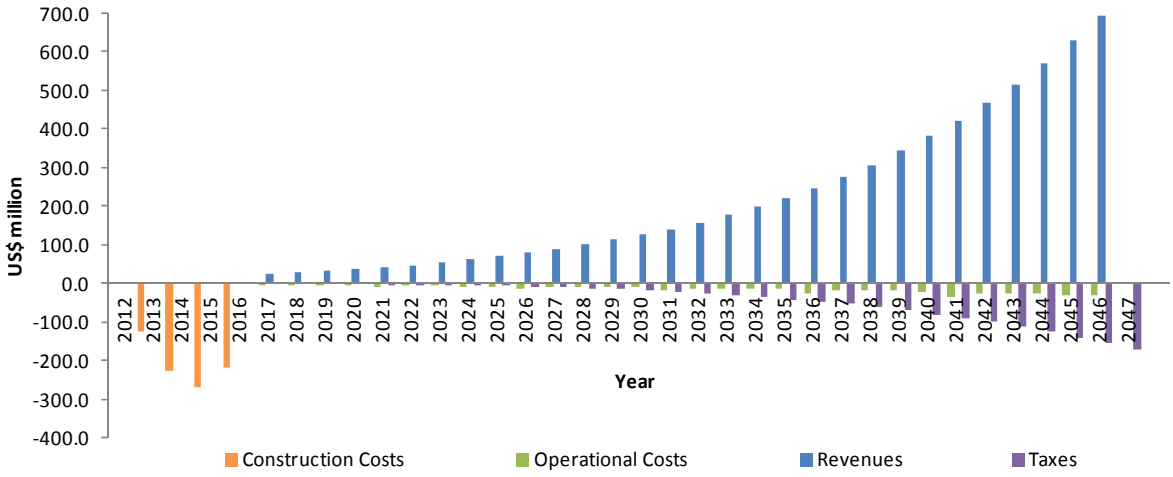


Figure 12.3.3.1-1 Cash Flow for Option 1 – 100% Government Financed

12.3.3.2 Option 2 – 50% Loan & 50% Government Financed

The funding gap is around US$305 million in NPV terms for the project. The cash flow under the assumption that half the funding gap is met by a government subsidy while the remainder is met through a loan is shown in **Figure 12.3.3.2-1**.

Summary	Alignment C	
	Undiscounted	PV@12% Discount Rate
Revenues	6,624.3	469.4
Operational and Replacement Costs	-485.8	-51.3
Capital Costs	-840.0	-446.4
Financial Costs	-554.9	-215.4
Tax	-1,413.4	-61.5
NPV	**3,330.1**	**-305.1**
FIRR		**7.3%**

Table 12.3.3.2-1 Financial Summary for Option 2 (US$ Million)

Notes: Undiscounted refers to the sum of the annual undiscounted value inclusive of inflation over the 35 years assessment period

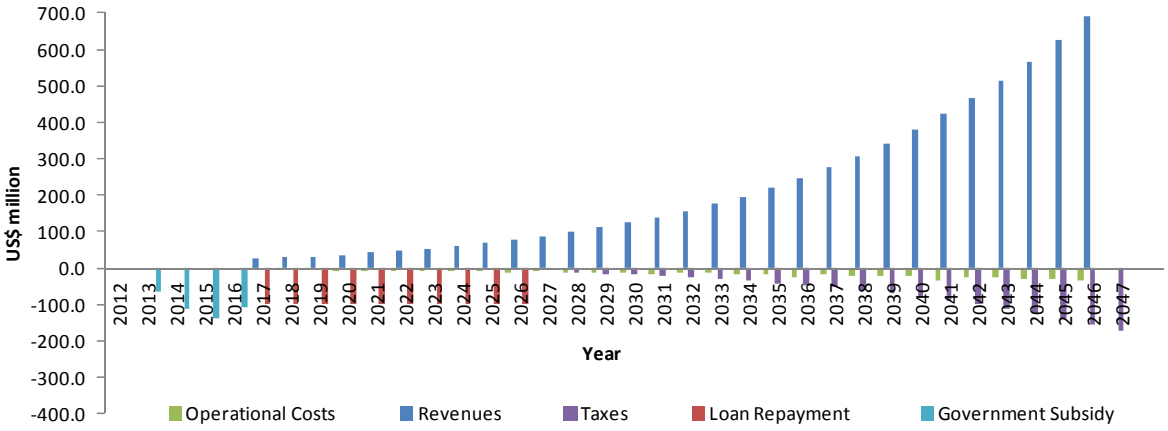


Figure 12.3.3.2-1 Cash Flow for Option 2 – 50% Government Financed & 50% Loan

12.3.3.3 Option 3 – 100% Loan

The funding gap is US$341 million in NPV terms. The cash flow under the assumption that the funding gap is met fully by a loan is shown in **Figure 12.3.3.3-1**.

Summary		
	Undiscounted	PV@12% Discount Rate
Revenues	6,624.3	469.4
Operational and Replacement Costs	-485.8	-51.3
Capital Costs	-840.0	-269.4
Financial Costs	-1,109.8	-430.7

Tax	-1,387.4	-58.9
NPV	**2,801.3**	**-341.0**
FIRR		**6.0%**

Table 12.3.3.3-1 Financial Summary for Option 3 (US$ Million)

Notes: Undiscounted refers to the sum of the annual undiscounted value inclusive of inflation over the 35 years assessment period

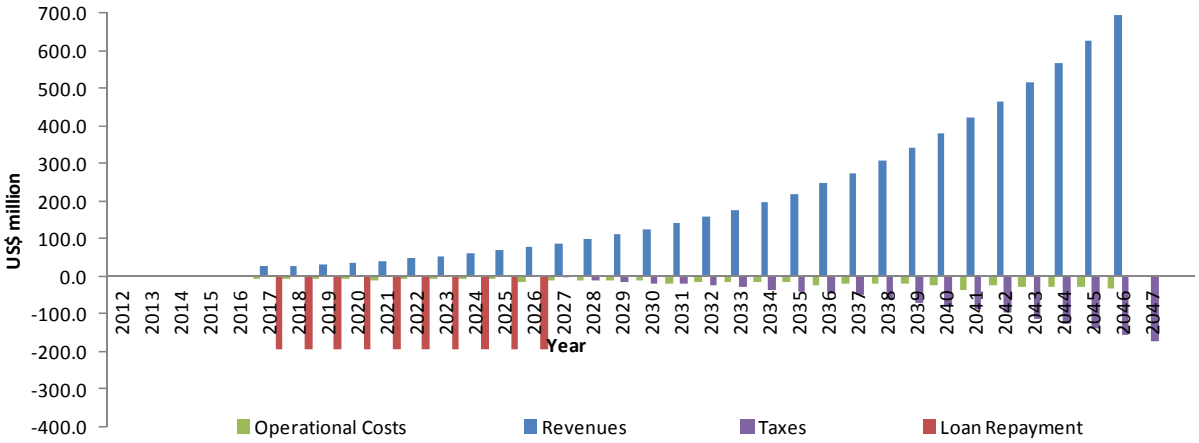


Figure 12.3.3.3-1 Alignment C Cash Flow for Option 3 – 100% Loan

12.3.4 Sensitivity Tests

A number of sensitivity tests have been undertaken to assess the impact of key parameters on the overall NPV and funding gap of the project.

12.3.4.1 Interest Rate

The base case assumes the interest rate to be 13% comprising a real discount rate of 5% and inflation rate of 6.4%. The impacts on the NPV of the interest rate ranging from 13% to 20% are tested and summarised in **Table 12.3.4.1-1**. As would be expected, the larger the proportion of debt that is involved in the financing model the greater the sensitivity of the NPV to the interest rate.

Interest Rate	Option 1	Option 2	Option 3
13% (Base)	**-274.6**	**-305.1**	**-341.0**
14%	-274.6	-325.3	-381.6
15%	-274.6	-346.2	-423.8
17%	-274.6	-390.8	-513.6
20%	-274.6	-464.2	-661.2

Table 12.3.4.1-1 Interest Rate Sensitivity Tests (NPV, US$ Million)

12.3.4.2 Toll Rate

Sensitivity tests around the toll rate per trip decreased by 20% were undertaken to test the impact on revenues and funding gap (**Table 12.3.4.2-1**). Logically the funding gap of the project increases with reduced toll revenues.

Toll Rate	Option 1	Option 2	Option 3
100% (Base)	**-274.6**	**-305.1**	**-341.0**
80%	-348.5	-382.2	-419.0

Table 12.3.4.2-1 Toll Rate Sensitivity Tests (NPV, US$ Million)

12.3.4.3 Traffic Demand

Sensitivity tests that decreased traffic demand by 20% were undertaken and the results are shown below (**Table 12.3.4.3-1**). The funding gap of the project increases with reduced traffic demand.

Traffic Demand	Option 1	Option 2	Option 3
100% (Base)	**-274.6**	**-305.1**	**-341.0**
80%	-348.5	-382.2	-419.0

Table 12.3.4.3-1 Traffic Demand Sensitivity Tests (NPV, US$ Million)

12.3.4.4 Capital Costs

Sensitivity tests that increased capital costs by 20% were undertaken and the results are shown below (**Table 12.3.4.4-1**). Clearly an increase in the capital costs will increase the funding gap.

Capital Costs	Option 1	Option 2	Option 3
100% (Base)	**-274.6**	**-305.1**	**-341.0**
120%	-394.8	-434.3	-478.1

Table 12.3.4.4-1 Capital Costs Sensitivity Tests (NPV, US$ Million)

12.3.4.5 Extension of Concession Period

The base case assumes the concession period to be 30 years. Sensitivity tests were undertaken that extends the concession period from 30 years to 40 years and the results are shown in **Table 12.3.4.5-1**.

Capital Costs	Option 1	Option 2	Option 3
30 years (Base)	**-274.6**	**-305.1**	**-341.0**
40 years	-182.8	-210.1	-245.8

Table 12.3.4.5-1 Extension of Concession Period Sensitivity Tests (NPV, US$ Million)

12.3.4.6 Loan Condition

The base case assumes financing is provided by private institutions that seek higher returns. Sensitivity tests were undertaken to assess the impacts on the NPV

if financing was provided by other non private institutions under concessionary or soft loan terms. The new assumptions adopted for the sensitivity tests are shown below:

- Interest rate of 4% to 6%
- Repayment period of 20 years

The results are summarised in **Table 12.3.4.6-1**. The project is financially viable under Option 3 at an interest rate of 5% or less.

Capital Costs	Option 1	Option 2	Option 3
Private Loans	**-274.6**	**-305.1**	**-341.0**
Soft Loans – 6%	-274.6	-145.8	-22.3
Soft Loans – 5%	-274.6	-128.9	13.0
Soft Loans – 4%	-274.6	-113.2	45.5

Table 12.3.4.6-1 Soft Loans Sensitivity Tests (NPV, US$ Million)

12.3.4.7 Conclusions

The results of the sensitivity tests are in line with expectations. The most significant parameters are capital costs, traffic demand, interest rate and loan conditions.

12.4 Summary of Findings

The preliminary findings of the financial analysis indicate that under the assumptions adopted, the tunnel, inclusive of toll revenues is not financially viable without government support. In summary, the key outcomes are:

- **Without Financing Costs** - The funding gap under Option 1 (Public Sector Comparator exclusive of financing costs) is estimated at US$ 275 million.
- **With Financing Costs** - Depending on the chosen financing option, the funding gap ranges from US$ 305 million to US$ 341 million.
- **Interest Rate** - Sensitivity tests using higher interest rates shows the funding gap ranges from US$ 325 to US$ 661 depending on the financing option.
- **Toll and Traffic Demand** - Sensitivity test around lower toll and traffic demand show that the funding gap ranges from US$ 349 to US$ 419 million depending on the financing option.
- **Capital Cost Escalation** - Sensitivity tests around higher capital costs show the funding gap ranges between US$ 395 million to US$ 478 million depending on the financing option.
- **Concession Period –** Sensitivity test around extending the concession period from 30 years to 40 years shows the funding gap ranges from US$ 183 million to US$ 246 million depending on the financing option.
- **Soft Loan** – Sensitivity test around lower interest rates and longer repayment period provided by Donor Institutions show that the project is

potentially financially viable under the financing option of 100% loan and at an interest rate of 5% or less with an extended repayment period.

The Bangladesh Bridge Authority will need to seek ways to meet this funding gap. There are a number of options including:

- A capital grant from the Bangladesh Government.
- Seeking soft or concessionary loans from Donor Institutions with extended grace periods and favorable tenor conditions to minimize the debt service burden.
- Using other incentive methods to entice potential investors such as land development rights.
- Exploring other revenue streams such as indirect taxes.

Each of these options could be considered individually however it is likely that a combination of options will be required to provide the best solution.

13. PROCUREMENT STRATEGY AND O&M PLAN

13.1 Procurement Strategy

Basically, two different ways can be considered for procurement strategy.

The first method and maybe the most cost effective way to construct a new tunnel is to use a 'Design and Build' type contract if the contractor is a competent international tunnelling contractor, where the contractor is responsible for both designing and constructing the tunnel. If this method is adopted, it is proposed to include a preliminary Front End Engineering Design to determine the level of drawings and specifications that are suitable for a Design and Build contract. However, the contractor could specify the wrong specifications and build a machine which is not suitable for the tunnel project if the contractor is not experienced in tunnelling. Client/Engineer has less control on the project because the contractor is controlling everything under the type of Design and Build Contract. Alternatively, the contractor may consider to rent a TBM.

In the second method, design and construction are separated i.e., Design-Bid-Build. A detailed specification will be prepared by the Engineer based on the ground investigation data and other site data. The contractor just needs to ask a TBM manufacturer to build the machine according to the specification. There is normally a buy back clause so the TBM manufacture will buy the machine back at the end of the project, and strip it and use the part on a new machine.

13.1.1 Financing Model (Capital Costs)

13.1.1.1 Financial Viability

It is recommended that the financing of the capital cost of the project does not involve transferring revenue risk to a private financier. With the uncertainty around toll revenues removed from the tender, bidders would need to make less allowance for price uncertainty and risk in their submissions. Instead, the Government would use annual toll revenues it receives during bridge operation to repay in part the costs of the successful bidder, with the remainder provided through contributions from the Government directly.

The division between Government subsidy and loan financing depends on the Government's priority in terms of balancing the following factors:

- Fiscal capacity to provide direct government subsidies/grants
- Reducing total net present value of payments made by the Government
- Reducing the annual payments
- Deferring the payments to the future

Ultimately such a decision rests with the Government but there is a balance between schemes that reduce upfront capital payments and spread them across smaller annuity contributions against a higher overall cost in present value terms.

13.1.2 Institutional Arrangements and Financing for Operation

Given the large capital expenditure on the project it is obviously important that robust arrangements are made for operation and maintenance in order to ensure the long term value of the investment.

The institutional set up for management, operation and maintenance needs careful consideration, particularly in view of the fact that it will be the only major tunnel in Chittagong.

There are two possible ways to address the issue of institutional capacity:

- Entrustment of appropriate Government bodies such as BBA tasked with management operation and maintenance, drawing upon previous experience in maintaining and operating bridges. As the operation of the tunnel is somewhat different to a bridge due to factors such as lighting, ventilation and safety, this would entail an additional degree of capacity building, recruitment and training during the design and construction process such that the institutions are prepared and ready to take over the facility at the completion of construction, or after several years of operation when Government bodies have been adequately trained.
- Transferring management, operation and maintenance to the private sector in the form of a Management, Operation and Maintenance (MOM) Contract. This is described in more detail below.

Although the construction of the project is likely to be subdivided into a number of packages it is expected to be more efficient if it is operated as a single package.

13.1.2.1 Management, Operation and Maintenance (MOM) Contract

Under a typical MOM Contract, a private entity is given a concession for a fixed period (typically five to seven years) to manage and operate the facility, collect toll revenue on behalf of the owner, inspect and maintain the facility etc. The contract is for a fixed price but additional or non scheduled works are paid separately. Payment is funded through toll revenues.

The benefit of an MOM contract is that it would attract skilled international companies to manage the project.

Although routine inspection and maintenance should be carried out by the MOM contractor and paid for under the terms of the MOM contract, abnormal maintenance may still require additional Government subsidy although the MOM contractor would implement the work.

The terms of an MOM Contract could include capacity building such that over time the Government becomes more involved with the technical aspects of operating and maintaining the facility.

13.1.2.2 Financing of the Management, Operation and Maintenance

Although the concession contract includes responsibility for toll collection, it is on behalf of the Government. Payments to the contractor are fixed and are not dependent on the tolls collected. In other words revenue risk has not been transferred to the contractor.

For the tunnel project, the estimated toll revenues are expected to be sufficient to finance the management, operation and maintenance. Therefore, it should in principle be possible to let an MOM contract which is financed solely from the toll revenue collected, dependant on any repayments required to service debt for capital costs. However, it may be necessary to include some risk mitigation measures (e.g. guaranteed minimum revenues) in order to make the contract sufficiently attractive to generate real interest.

An advantage of transferring revenue risk to the contractor is that it gives them an incentive to maximise the availability of the facility. However, another way of achieving the same thing is for the terms of the contract to include penalties if availability/levels of service do not meet contractual targets.

A disadvantage of transferring revenue risk is that the Government will inevitably have to relinquish some control over the ability to modify the toll level. Since the MOM contract is renegotiated every five to seven years the financing arrangements do not have to remain constant throughout the lifetime of the facility. Once the tunnel has been open and running for a number of years the uncertainty with respect to revenues should be significantly reduced. One strategy would be to bid the MOM contract on a fixed price basis for the first contract with the intent to reconsider alternatives for future contracts.

13.1.3 Division of the Project into Construction Packages

13.1.3.1 Rationale for Multiple Construction Packages

The Multi-lane Road Tunnel under the River Karnaphuli River is a large-scale project in Bangladesh. If it was procured as a single construction contract, only joint venture consortia including very large contractors would be expected to bid. This could result in limited competition. For example if only one or two qualified consortium expresses interest in the project then it cannot realistically proceed due to lack of competition. If there are three consortia the tender can proceed but there is still a risk that one of the consortia could withdraw or attempt to influence the project by threatening to withdraw.

If the project were a privately financed concession where commercial operation of the facility by collection of toll revenue were transferred to the construction consortium then it would be an unavoidable consequence that a large part of the capital works would have to be let as a single contract under the concession since it is not a practical proposition to subdivide the commercial operation of different parts of the route to different parties. Therefore as a concession the project would not be divisible and the risks of limited competition would be unavoidable.

The financial analysis has shown that the project is not viable on a commercial basis and unlikely to attract private sector finance such as under Design Build

Finance Operate Maintain (DBFOM) models. Although there are financing options on a loan basis that have been explored, these do not require the contractors who finance and build the project to also take on responsibility for commercial operations.

It is therefore recommended that the project is split into different packages in order to reduce the risk of limited competition.

Since the nature of the construction works varies along the alignment, the construction can be split into appropriate contracts such that there will not be a significant loss in economy of scale compared to a single contract. Also described below is a way in which contractors can be allowed to bid concurrently for multiple packages in order to give the opportunity for economy of scale discounts to be offered if they are present.

Another benefit of dividing the construction into packages is that it gives more opportunity for local contractors to be involved in contracts suitable for their skills and experience.

13.1.4 Proposed Construction Packages

A total of five construction packages are recommended as shown in **Error! Reference source not found.** below. These are namely:

Section 1 – Patenga Side Link Road Section

- Package 1 – At-grade road, Planned Costal Road of Bengal Bay connection to the Patenga Tunnel Portal which will be connected to the Dhaka Truck Road. The tunnel portal will also connect to the existing Sea Beach Road which may require expansion and reconstruction.

Section 2 – Patenga Side Cut & Cover and Open Cut Tunnel Section

- Package 2 – Patenga Side Cut & Cover and Open Cut tunnel sections connecting to Planned Costal Road and/or Sea Beach Road.

Section 3 – Karnaphuli River Tunnel Section

- Package 3 – Tunnel Section to be constructed by TBM including launching shaft on the Patenga Side and retrieval shaft on the Anowara Side.

Section 4 – Anowara Side Cut & Cover and Open Cut Tunnel Section

- Package 4 – cofferdam, Anowara Side Cut & Cover and Open Cut tunnel sections connecting to existing local road.

Section 5 – Anowara Side Land Section

- Package 5 – River viaduct, toll facilities (civil works), office building and at-grade existing local road connection to the Anowara Tunnel Portal, which will be expanded and re-constructed, then connect to the Banskhali Sarak Road-Cox's Bazar Road.

Although the civil works are divided into geographic packages, there are some items which should be carried out on a route wide basis.

- Package 6 - Toll facilities (structural and systems), Traffic Control and Surveillance Systems (TCSS) and utility installation.

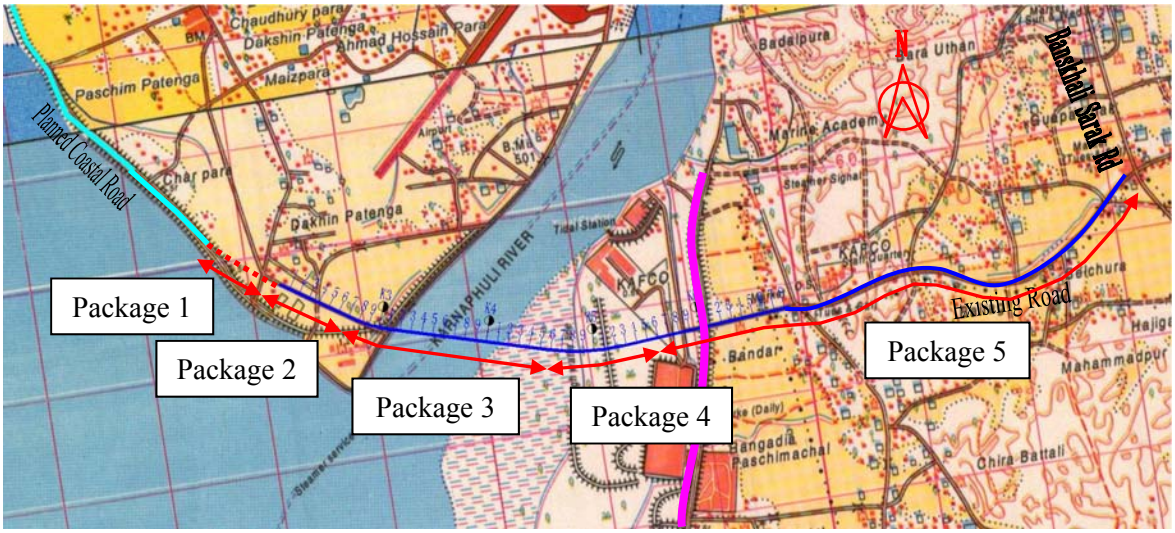


Figure 13.1.4-1 Recommended Construction Work Packages

Further splitting of the packages is possible but not recommended as this will increase the number of interfaces between packages and reduce the economy of scale without any further benefits from the increased competition. However, Package 5 could reasonably be further subdivided if it were desirable to do so for the sake of making a number of small contracts suitable for local contractors.

The work packages are discussed in the following subsections.

13.1.4.1 Package 1 – Connection to Planned Costal Road and/or Sea Beach Road

This package comprises at-grade connection road to Planned Costal Road of Bengal Bay and Sea Beach Road including the structure up to the tunnel entry or portal. This package is relatively small compared to the other packages but is a reasonable sized project for a local contractor. It is anticipated that conventional construction skills in Bangladesh can be employed to construct this section.

13.1.4.2 Package 2 – Patenga Side Cut & Cover and Open Cut Tunnel

This package comprises the Patenga Side cut & cover tunnels and open cut tunnels (including portals) and the structures in between the tunnels. The total length is about 410m. This package requires specialist tunnelling, excavation and lateral support skills.

13.1.4.3 Package 3 – Karnaphuli River TBM Tunnel

This package comprises the tunnels from the Patenga Side launching shaft to the Anowara retrieval shaft. The length is about 1.6km. This package requires construction of tunnels with TBM. It will require specialist skills. It should be noted that due to complexity of works, construction of this package is likely to be on the critical path for the completion of the whole project.

13.1.4.4 Package 4 – Anowara Side Cut & Cover and Open Cut Tunnel

This package comprises the Cofferdam, Anowara Side cut & cover tunnels and open cut tunnels (including portals) and the structures in between the tunnels. The total length is about 640m. This package requires specialist tunnelling, excavation and lateral support, earth work skills.

13.1.4.5 Package 5 – Connection to River Viaduct and Existing Local Road

This package comprises the river viaduct from the tunnel portal to the existing local road, including link road to the Banskhali Sarak Road-Cox's Bazar Road. The length is about 4.15km. This package requires construction of bridge structures over a river and the expansion and re-construction of at-grade link road. There will also be some civil works associated with the toll plaza as well as the office which will be located next to the toll plaza.

Depending on the outcome of detailed design, it may be possible that a clear geographical split is available between different types of construction. If the works are suitable for local contractors, then further splitting the package may be beneficial in terms of getting more local involvements. This can be reviewed again at the detailed design stage.

13.1.4.6 Package 6 – Toll facilities (structural and systems), Traffic Control and Surveillance Systems (TCSS) and utility installation

This package comprises Toll facilities (structural and systems), Traffic Control and Surveillance Systems (TCSS) and utility installation. The facilities and utilities within the whole project area should be included. This package requires special skills.

13.1.4.7 Bidding for Combined Packages

As noted in above, part of the recommended strategies for dividing the project into packages is to allow bidding for combined packages to give the opportunity for contractors to offer discounts due to economies of scale. To make the tender assessment manageable it is not envisaged that contractors are allowed to offer prices on any and all possible combination of the first five packages. There are two combined packages where economy of scale savings is likely and these are discussed below.

13.1.4.8 Cut & Cover and Open Cut Tunnel Sections

The construction works for Packages 2 and 4 (the cut & cover and open cut tunnel sections) require similar skills and thus there will be economy of scale if all the works are carried out by the same contractor. The total length is 1.05km which makes it a large package but it is not out of scale since some of the equipments can be shared between the two packages. It is recommended that Packages 2 and 4 are tendered concurrently and that contractors are allowed to offer a discounted

price for the combination of the two packages. This means that if there is any cost saving in combining the packages, this will be realised in their tender proposals.

It is recommended that contractors are also allowed to bid for these packages individually to increase competition.

13.1.4.9 Patenga Side Section

Similarly there could be potential cost savings by combining Packages 1 and 2. In this case it is not so much economies of scale that will lead to potential savings but more the potential logistical simplification that could be achieved by a single contractor having access to the entire Patenga construction area. The total length is around 1.15km which again becomes a large package which may not attract enough competition. It is possible that a similar strategy could be followed and that during tendering contractors are allowed to bid for Packages 1 and 2 concurrently and are allowed to offer a discounted price for the combination of the two packages.

However, this would tend to reduce the competitiveness of local contractors for Package 2 and is an contradicting strategy to the one of combining Packages 2 and 4. Therefore whether or not to allow discounted prices for the combination of 1 and 2 should be considered carefully in light of how much it is desired to involve local contractors.

13.1.5 Procurement of Design and Construction

13.1.5.1 Options to be considered

Our discussions and recommendations with respect to the procurement of design and construction for the project are based on the following assumptions:

- The project is subdivided into construction packages of a reasonable size;
- The construction companies, although they may finance the tunnel in whole or in part through loan arrangements will not take on commercial operation of the tunnel;
- If the tunnel is operated commercially, this will be let separately to the construction contracts.

Given these assumptions there are three basic alternatives that can be considered for the procurement of the design and construction of the tunnel:

1. **Design-Bid-Build** – The detailed design of the project is carried out by a consultant appointed by the Government. The consultant then develops the design, tender and contract documentation for inviting and awarding the construction contract on a traditional basis. The consultant supervises and administers the construction contracts.
2. **Early Contractor Involvement** – This is a variation on Design-Bid-Build where the contractor is appointed before completion of detailed design. The successful contractor is selected on the basis of capability, approach, construction methodology and price. After selection the

contractor becomes heavily involved in the finalization of the design based on preferred construction methods

3. **Design and Build** – The Government appoints a consultant to develop tender and contract documentation for inviting and awarding construction contracts. The document includes a Specimen Design and detailed Employer's Requirements which set out the contractual requirements. The detailed design is then prepared by the contractor in compliance with the Employer's Requirements.

The common feature of the above procurement options is that the Government appoints a consultant to develop the design and prepare tender and contract documentation. What varies is the extent to which the Government retains control of the design through its appointed consultant as opposed to handing over certain aspects of the design to the contractor.

13.1.5.2 Discussion of Options

The advantage of a traditional method is that the Government has full control over aspects such as durability, aesthetics, provision for operation and maintenance, environmental impact etc. The advantage of the design and build method is that it allows aspects of the design to be tailored towards the specific skills and equipment of the tendering contractors which can lead to cost savings. However, it is important to ensure that the procurement process does not result in simply sacrificing quality in order to make the construction cheaper. It is not absolutely necessary that the same approach is followed for all of the packages. For example a traditional design-bid-build approach for the link road would ensure the quality and durability of the structures. On the other hand, an early contractor involvement approach for the TBM tunnel sections would allow tailoring of the design to the specialist construction equipment necessary for the tunnel construction whilst retaining sufficient control to ensure the durability of the structures can be retained. Additionally, design and build method can be applied to the two packages of cut & cover and open cut tunnel sections which allows contractor to optimise the designs on temporary works such as the ELS strutting system. In addition, this allowed detailed Employer's Requirements to be written which ensure the quality of the project and meet the Government's objectives in every aspect. At the same time sufficient flexibility is left to the contractors to allow them to optimise the design to their techniques and equipment. In this way the design and build genuinely leads to cost savings due to optimisation rather than reduction in quality.

13.1.5.3 Interfaces with Design and Construction

Based on the stakeholder consultation meetings, there are certain known interfaces with other planned projects. For example, Planned Costal Road and Sea Beach Road, as well as improvement of the existing Banskhali Sarak Road. Nevertheless, facility and utility provisions should be considered carefully:

13.1.5.3.1 Facility and utility provision

Toll facilities, Traffic Control and Surveillance Systems and utility installation is under consideration for the tunnel and the technical aspects associated with these

facilities and utilities have been discussed in other chapters. Provisions of utilities will require special consideration during the detailed design and construction of the tunnel so the requirements should be discussed and confirmed as early as possible during the detailed design phase.

It should be noted that utility provision will require significant associated works and will hence lead to interfaces for the tunnel civil works packages. It is recommended that installation of utilities on the tunnel be considered as a route wide contract (i.e. Package 6) to simplify the interfaces.

The provision of a corridor for telecommunication cables is also desirable and will similarly require discussion and confirmation. This is likely to have less impact compared to the transmission of fresh water but should not be neglected during the detailed design.

13.1.5.4 Coordinated Design

Although it is recommended to subdivide the project into different packages for construction we would recommend that the Government's design consultant is appointed for the whole of the project. This has the following advantages:

- Avoids the Government having to manage and coordinate multiple consultants;
- A consistent approach to design is taken throughout the entire project so that it is developed as a single whole rather than a collection of parts;
- Maintenance provisions will be consistent throughout so that the party responsible for maintenance will not have to adopt different procedures in different parts of the project (except as necessary due to structural type);
- Aesthetics and appearance will be coordinated throughout the project;
- Interfaces will be handled by a single consultant (e.g. interfaces between contracts and related to utilities within the tunnel). This will lead to coordinated solutions.

This is especially important if a design and build route is followed where it is then absolutely necessary that the Employer's Requirements for all packages are written by the same consultant to ensure a coordinated approach.

13.1.5.5 Consultant's Main Duties

A brief description of the main duties which it is anticipated that the client's consultant will complete up to award of contract includes:

1. Finalise options and the preliminary design in consultation with the client including reaching decisions on key aspects such as:
    - Alignment
    - Functional cross section
    - Structure types

- Tolling arrangements
- Provision of utilities

2. Finalise the procurement method working with the client to decide on the contract packaging, procurement and scheduling of each package.
3. Carry out the detailed design Environmental Impact Assessment which will be a parallel study over the course of 12 months. The EIA will start as soon as possible for collection of baseline data with respect to seasonal change. Detailed aspects of the EIA will be carried out once the options and preliminary design are finalised and the full project details are known.
4. On behalf of the client, procure and supervise additional ground investigation and surveys. The most significant of these is the ground investigation which must be carried out in more detail once the alignment and options have been finalised. Other investigations and surveys will include topographic survey, bathymetric survey etc.
5. Complete the detailed design of the project including development of specifications and design criteria.
6. Prepare tender documentation incorporating the detailed design and specifications as well as draft contracts, environmental requirements, health & safety and quality control requirements etc. Assist the Government with prequalifying suitable contractors and managing the tender process including assistance with tender assessment.

In the event that a design and build route is followed then instead of carrying out the detailed design the consultant would complete a Specimen Design to a high degree of details and the tender documents would also include detailed Employer's Requirements giving guidance to the contractor on the expected outcome of the contractor's detailed design.

13.1.6 Implementation Programme

The provisional programme for the implementation is illustrated in the Master Plan Programme (MPP).

The MPP programme is based on commencement in 2013 and with an initial period to finalise option selection and update and develop in more detail the preliminary design based on the selected project configuration. During this initial period the details of the construction packaging and procurement methods would also be finalised. This will include development of a detailed implementation programme which will reflect the contract packaging, procurement method for each package and construction duration for each package.

After this initial period the selected procurement method would be followed for the detailed design and construction. As described above, a combination of procurement methods could be adopted for different packages. It can be seen from the MPP programme that the overall procurement time does not differ significantly between the different options. For the traditional Design-Bid-Build method there is 8 months of detailed design inclusive of tender documentation and a seven month period to invite tenders, assess the tender returns and award the contract. Traditionally these activities would be sequential, but a time saving can

be made by overlapping detailed design with the tender period and this has been shown on the MPP programme. This means that the tender would initially be called without all reinforcement details being available and these would be provided to the tenderers in an addendum. After tender assessment and award, construction may commence immediately.

For the Design and Build alternative, the tender documentation and specimen design can be produced in four months meaning that the Request For Proposals can be issued earlier than for a traditional procurement route. However, more time has to be allowed for the tender itself since the contractors have to prepare tender designs and spend more time evaluating risk. Furthermore, construction cannot start immediately after award of contract since the detailed design still has to be prepared. Typically the lag between award and commencement of construction will be around four months. Overall, the procurement time for design and build is slightly longer.

Early Contractor Involvement is similar to Design and Build in that the Request For Proposals can be issued early and the detailed design takes place after award of contract. However, in this case the contractor does not have to prepare a tender design so the tender period can be the same as for the Design-Bid-Build method.

For all procurement strategies we have assumed a construction period of 32 months which is reasonable for a project of this scale. Not all of the packages will require 32 months and the detailed procurement schedule will reflect this to allow the critical path for the project to be readily identified and to ensure that the focus of the team is on commencing construction of the critical packages as early as possible.

13.1.6.1 Acceleration of the Programme

Options are available to accelerate the Master Plan Programme if required. In principle there are two main ways to achieve earlier completion of the project:

- Start construction earlier
- Allow less time for construction

Considering the scale of the project, shortening the time allowed in the MPP to prepare the designs and tender documentation as well as to invite tenders, assess and award could introduce compromises in quality or additional costs. If the design time is reduced, it is still possible to complete the design with additional resources but decision making by both the Government and the consultant will be driven to some extent by expedience. Furthermore, a reduced tender period gives the contractors less time to evaluate risk and determine favourable offers for the contracts. Finally reduced design time gives less opportunity to optimise the design towards rapid construction.

Shortening the time allowed for construction would require the contractors to mobilize additional plant and labour to complete the job. Furthermore the ability of the contractor to negotiate favourable commercial terms for supply of materials would be reduced. Therefore acceleration of the construction is likely to result in an increase in cost.

Nevertheless, if it is desired to shorten the programme the available options can be explored in more detail. Master Plan Programme is shown in **Figure 13.1.6.1-1**.

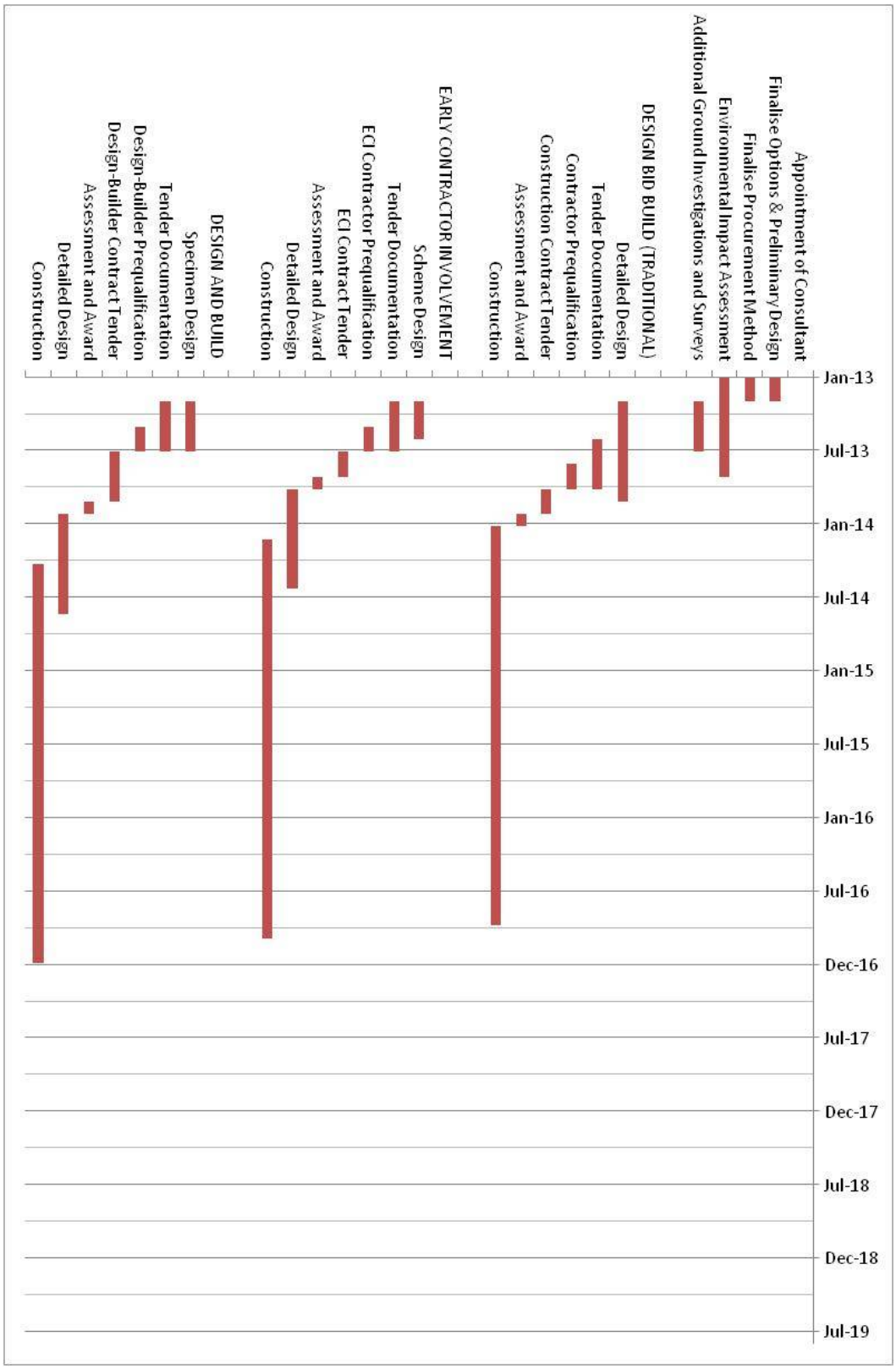


Figure 13.1.6.1-1 Master Plan Programme

13.2 O&M Plan

13.2.1 General

The recommendations on maintenance and operation of the Multi-lane Karnaphuli River road tunnel, and considerations of the refined road layout, the proposed management, operation and maintenance strategies to be adopted in the detailed design of Karnaphuli River road tunnel are summarised as follows.

13.2.2 Tunnel Management

13.2.2.1 Management, Operation and Maintenance Contractor

It is possible to outsource the management, operation and maintenance (MOM) activities for the Karnaphuli River road tunnel under a contractual agreement after the tunnel be constructed and put into operation. The advantage of outsourcing MOM is that the contractor will establish its own asset management and works supervision systems in a more cost-effective way, while performance standard defined by the government are met. On this approach, the government administrative works and technical supports in different specialist for tunnel operation and maintenance of E&M facilities can be simplified and efficiently managed.

Below is an outline of minimum type of works proposed under MOM package which include:

Routine Management and Operation Arrangement

(a) Provide mobile patrolling of the Karnaphuli River road tunnel area and associated connected slip roads and approach roads by patrol car along any defined patrol schedule and patrol route;

(b) Control of air quality inside tunnels for all conditions including stationary traffic, slow moving traffic, normal traffic, traffic incident and accident cases, vehicle breakdown etc.;

(c) Provide detailed working arrangement for single tube operation to allow contra-flow movement during night-time (provisionally) and any specified period to facilitate regular tunnel inspection activities for any repair, rescue to tunnel facilities, and the re-opening of tunnel tube to traffic afterwards.

Traffic Arrangement under Emergency

(a) Provide resources and working arrangement for various types of incidents as defined;

(b) Provide resources and working arrangement for various types of traffic accidents as defined;

(c) Provide resources and working arrangement for various types of emergency situations including fire, power supply loss, as defined;

(d) Provide resources and working arrangement for vehicle recovery and rescue operations, covering staff mobilisation and vehicle deployment

plans for cordoning off the incident spots and direct traffic, thereafter to provide recovery operations including possible towing and winching means for vehicle treatment;

(e) Arrange communication with other parties including adjourning TCS control, government parties, media, motorist, other public transportation organisation in dealing with various type of incidents, accidents, and emergency situations;

Services on Operation and Maintenance

(a) Provide operation and schedule maintenance of E&M facilities, systems for transport facilities.

13.2.2.2 Overall Management Structure

In broad terms, the tunnel operation is part of the road tunnel area, which has a dedicated management structure and resources to operate the tunnel. The Karnaphuli River Road Tunnel Area is responsible for traffic surveillance and all aspects concerning the safe operation including response to incidents and emergencies. The day to day operation of the tunnel for traffic passing through it will be administered from a main control centre located at the administration building on the Anowara Side near the toll stations.

The tunnel organisation has four main fields of responsibility: routine operation; plant operation; maintenance; and rapid co-ordinated emergency response. The fields are divided into two staff divisions, namely the operations division and engineering division.

The operations division will be responsible for managing and controlling traffic safety within the tunnel area. The operations division will also be responsible for the immediate summoning of the necessary emergency services, for immediate control of traffic entering the tunnel and provide necessary control of the lighting and ventilation as required.

The engineering division will be responsible for the maintenance of E&M tunnel plant to maintain a safe environment for the tunnel. The engineering division is also responsible for the more labour intensive works of tunnel maintenance including cleaning and painting.

Administrative and general support functions are the responsibilities of the administration sector under operations division.

13.2.3 Operational Arrangement

13.2.3.1 Normal Operations

In normal circumstances, traffic will pass through the tunnel without stopping. Tunnel traffic will be regulated even in normal conditions to ensure safe operation, minimise incidents and maximise flows. Operation Scenario will include:

(a) Lane changing is not permitted in the tunnel;

(b) Goods vehicles carrying dangerous goods, overweight and out-of gauge vehicles will not be permitted to use the tunnel;

(c) Escort service within the tunnel area is part of the tunnel operator's duties and the escort service is subject to a fee under the tunnel legislation;

(d) Buses kept to nearside lane;

(e) Goods vehicles of a permitted gross vehicle weight exceeding 5.5 tonnes shall be kept to nearside lane;

(f) Climbing lanes inside the tunnel will be provided at both ends for road gradient larger than 3%. Buses and Heavy Goods Vehicles (HGVs) need to use climbing lane;

(g) Use of dipped headlights within the tunnel;

(h) Tunnel jet fans are controlled automatically with manual override as required by the levels of emissions and visibility. These are monitored by the sensors and the fans operated via the Central Monitoring & Control System (CMCS) from the Administration Building;

(i) The tunnel lighting is controlled by the CMCS from data via input from photometer value installed at tunnel portal and dawn/dusk timer.

13.2.3.2 Operations during Planned Maintenance

(a) Operations during planned maintenance relate to the planned closure of one tunnel tube to enable maintenance, with contra-flow traffic in the other tunnel tube. Crossovers are provided at each end of the tunnel to facilitate contra-flow operations.

(b) The traffic plan for contra-flow will be implemented from the main control centre and use staff and vehicles from the east end and/or west end control points or kiosks.

(c) Planned closure of one tunnel tube will be during times of least traffic, i.e. night-time. Closure of tunnel tube for routine cleansing, servicing and maintenance takes places normally from 1:00a.m. to 6:00a.m (Provisionally).

(d) The planned and routine maintenance is carried out in the closed tunnel tube. Tasks and activities are scheduled to fit the closure period.

(e) Standards or specifications which direct the level or manner of maintenance for specific asset items or equipment will be referenced in the appropriate maintenance manual and procedure.

13.2.3.3 Emergency Operations

(a) The majority of incidents experienced such as vehicle breakdowns and physical damage can be classed as minor incidents. Minor incidents require the attendance of a rescue team normally consists of 3 operation staff. A patrol car and a recovery vehicle will be mobilised to attend the incident. Also, tunnel users will be informed through the Public Address (PA) system regarding the incidents.

(b) A major incident includes the possibility of personal injury or loss of life, fire, significant damage to property and serious disruption to the traffic flow. The control centre will control all traffic measures for major incidents.

(c) During a major incident, the affected traffic lanes or tubes will be closed. The operations staff will be responsible for summoning the emergency services. Traffic signals and lane use signals will be activated. Vehicles inside the tunnel section will be clearly as soon as possible with the directions from the tunnel operations staff. In the case that requiring temporary closure of the Karnaphuli River Road Tunnel, "Tunnel Closed" signs at the entrances of the Tunnel Area will be activated to prevent traffic from entering the Tunnel Area.

(d) In case of the risks identified requiring emergency evacuation, all the affected people inside the tunnel section will be notified to evacuate the tunnel using the adjacent tunnel tube via the cross passages.

(e) Emergency services such as ambulance, fire appliances and police could gain access to the tunnel through using the crossover at the west end, and the over height/weight vehicular access and crossover at the east end.

(f) The detailed evacuation procedure, fire fighting and rescue procedure, operation of smoke extraction system and, use of emergency equipment and cross passage shall be further liaised with relevant government department and developed at later stage of the project Design Phase.

(g) Recording and reporting systems should be developed electronically by the operating systems. The event log file should provide a record sufficient for audit purposes and the review of event sequences. The log should be automatically updated when a system changes state and be capable of accepting comments entered manually by the tunnel operator.

(h) Post-incident analysis and evaluation is done in order to improve the safety of users, employees and emergency services personnel. To ensure an unbiased approach, any investigation regarding responsibility has to be excluded from this phase of the investigation. These processes can also lead to improvement of productivity and cost reduction in future tunnel design and systems. From a safety perspective, the post-incident analysis assists in the review of the human, material or financial consequences of incidents (including fires) to improve operational safety.

13.2.3.4 Prohibited Vehicles (Goods vehicles carrying dangerous goods, overweight and out-of gauge vehicles)

(a) DGV are intercepted at control kiosk and stopped at lay-by for prosecution and subsequent diversion.

(b) Upon detection of over-height vehicle by detector at slip road and tunnel approach, the over-height detection system will provide an

activation of primary detector. A designated stop sign shall be activated to provide a "Stop" display; the over-height vehicle shall then be identified at the control kiosks and directed to lay-by for prosecution, temporary detention and subsequent diversion.

(c) The over-height detector will also have the Variable Message Sign (VMS) activated with a message. Together with lane control signals activated to red cross and a traffic light indication, the over-height vehicle shall be identified by ground level staff at control kiosk and be diverted via the over-height vehicular access.

(d) In the situation of suspected overweight vehicles, the operations staff in the control kiosk will intercept and divert the suspected vehicles to the weighbridge for checking the weight. The affirmed overweight vehicles will then subject to prosecution and be diverted through the overweight vehicular access.

(e) At the Anowara side, prohibited vehicles approaching the tunnels will not be allowed to enter the tunnel.

(f) At the Patenga side, prohibited vehicles from will not be notified by message signs and not allowed to pass through.

13.2.4 Facilities for Management, Operation and Maintenance of the Tunnel Area

13.2.4.1 Administration Building in Anowara Side

The control room, administrative offices, workshop facilities, storage areas, staff supporting facilities and car parking area will be included in the compound area for the administration building.

13.2.4.2 Control Room

The control room will be equipped with the tunnel control and operation equipment and facilities for efficient response to incidents on Karnaphuli River Road Tunnel and tunnel approach roads. The operation control room may also be directly in charge of various control kiosks.

13.2.4.3 Control Kiosks

A kiosk is a small size permanent structure for the accommodation of up to 3 operator's staff. Its primary function is providing on-site monitoring of traffic conditions, incident response and interception of prohibited vehicles. A kiosk should be located on the upstream side of the lay-by. The kiosk shall have good visibility towards both mainline and slip road traffic but shall be well protected from vehicle impact.

Locations and details of the control kiosks will be further liaise and confirmed with relevant departments in the Design Phase.

13.2.5 Turn around and Diversion Facilities at Portal

Approximately 700m long crossover facilities are provided near the road tunnel west portal and east portal areas to facilitate cross-over during contra-flow operation and the turnaround of operational vehicles and emergency vehicles in both directions.

13.2.5.1 Other Facilities

Fully Variable Message Sign (FVMS)

Fully Variable Message Signs are provided along the approach roads to the tunnels which serve the purpose for conveying message and sign to the drivers approaching to the Karnaphuli River road tunnel area. The FVMS is to provide message to the drivers regarding the operation and conditions of the road tunnel before they entering into the road tunnel area. FVMS should be placed at an adequate distance upstream from interchange point so that motorists could have ample time to digest the messages displayed on FVMS and then respond.

Over Height Vehicles detectors (OHVD)

Over height vehicles detectors made of dual infra-red beam and ground loop are used to detect over-height vehicles approaching the tunnel portal. The detectors are installed along the approach roads to the tunnels at two ends of the tunnels with beam transmitters and sensors to be mounted on either gantries or poles.

Variable Message Sign (VMS)

Variable Message Signs are provided along the slip roads at two ends of the tunnel area which serve the purpose for conveying message and sign to the drivers. The VMS will be installed approximately 100m after the OHVD. The VMS is to provide message to the drivers to alert and pay attention to the lane control signal in case over-height is detected.

Lane Control Signal (LCS)

Lane control signals are installed along the approach roads at two ends of the tunnels and inside the tunnels for controlling lane usage of the tunnels. The LCS will be installed approximately 100m after VMS. The LCS will provide signal to the drivers to stop at the lay-by beside the control kiosk in case over-height is detected.

Weighbridge

Weighbridge is provided in the lay-by outside the control kiosks at both ends of the tunnel for weight measurement of the suspected overweight vehicles.

Lay-by

Prohibited vehicles are required to be stopped at the lay-by located before the tunnel portals. The lay-by should be provided on the left of the approach road near the control kiosk. The lay-by should be located downstream of the last slip road merging with the main road.

Radio Rebroadcasting System

Radio rebroadcasting system will be provided to cover the whole tunnel area which will rebroadcast the public FM and AM radio channels in Chittagong throughout the tunnel. Radio break-in facility will also be incorporated to facilitate the broadcast of messages and instructions from the tunnel operators to the motorists using the tunnel. 'Turn On Radio' signage should be erected at tunnel portal to alert the motorists to turn on the radios inside their vehicles for possible emergency message broadcasting.

Cross Passages

Passenger cross passages are provided inside the tunnels at approximately 700m intervals with a clear dimension of approximately 5m wide and 2.1m high. The function of the cross passages is for evacuation during emergency situations which provide passage between two tunnel tubes.

The cross passages are equipped with 2 hours fire-resistance self-closing door equipped with fixed self illuminated exit sign. Depending on the type of fire hazard, smoke detectors are to be provided within the cross passages and E&M plant rooms inside the tunnels. In addition to the fire detection system, open and close signals of isolation and sectional valves will be monitored by the tunnel fire control panel to prevent the smoke from entering the cross passage area.

Niches

Emergency Niches should be installed at regular intervals of 100m throughout the tunnel section. A self-illuminated sign should be provided above each niche and each niche should be equipped with Emergency telephone, Fire extinguisher, Break glass, Power point and there should be hydrant niches providing hose reels and hydrants for fire fighting.

13.3 Summary

The financial model of the Karnaphuli River Road Tunnel have been carried out which reveals the project will only be commercially viable with Government support. The financial revenue from the project will not provide sufficient return for a private investor to fund the capital cost of construction. The institutional arrangements and financing for operations also suggests possible arrangements while tunnel is in operation stage. The project is anticipated to be divided into packages for construction such that it provides more opportunities for local contractors to get involved in contracts suitable for their skills and experiences. Several procurement strategies including Design-Bid-Build, Early Contractor Involvement and Design & Build have been proposed for different packages in the river tunnel project in order to optimise the construction programme, cost and quality of the tunnel. Guidelines for the tunnel during its operation stage and under emergency operations have been provided in the O&M Plan.

14. CONCLUSIONS AND RECOMMENDATIONS

After several months' detailed investigation and study, some conclusions and recommendations are made as below:

1. Based on the traffic survey, analysis and forecast, demonstrated by expressway service level analysis, dual-two lanes expressway standard with design speed of v=80km/h is recommended for Alignment C with considerations of road network plan, traffic volume forecast, overall transportation system, and long-term development of the project area.

2. Based on site visits and data collected, several alignment options proposed are analyzed, compared, and screened.

    - Alignments A, B, and C are taken as the options to be studied in detail in feasibility study stage. After comprehensive analysis and comparison, from the aspect of service function, traffic function, construction scale, construction risk and construction cost, Alignment C is recommended at the current stage.

    - The principal part of Alignment C adopts the expressway standard and the approach road adopts the urban trunk road functions, both of them are dual-two lanes with design speed of 80km/h.

3. The topographic and bathymetric survey, geological and geotechnical investigation, hydrological survey indicated that Alignment C is engineering feasible.

4. Based on the results of traffic survey, analysis and forecast, topographic and bathymetric survey, geological and geotechnical investigation, hydrological survey, a preliminary design of tunnel and tunnel construction method is made following the international standards and codes (US, BS, China et al):

    - Dual two-lane tunnel design without non-motorized vehicle lane and sidewalk is recommended at the current stage.

    - Cross section type of twin-tube dual two-lane is recommended at current stage.

    - Through comprehensive comparison among the various tunnel construction methods suitable for this project, shield-driven method is recommended for tunnel construction.

    - Design for major technical parameters of shield segment is made at the current stage. The segment for shield tunnel is 10.8m in diameter, 0.5m in thickness and 2m in ring width. Common segment with taperness of 36mm is adopted. The segment separation adopts the way of 5+2+1, i.e. total 8 pieces, including 5 standard pieces, 2 adjacent pieces and 1 capping piece. Both ring and longitudinal joints of segment adopt inclined bolt connection.

    - Envelop enclosure type for bank side sections and working shaft are compared and analysed at current stage; Sheet pile, SMW pile construction method, bored cast-in-place pile and diaphragm wall are

adopted respectively as envelop structure in accordance with different excavation pit depths.

- According to structure stress and concrete durability design requirements, preliminary design on material and size of main structure is made.
- Preliminary research on waterproofing structure of shield segments and bank side section structure is made at the current stage.

5. Based on the quantity from preliminary tunnel design and unit rates of labor, machinery and material in the local market and international market, construction cost, maintenance cost and operation cost of Alignment C is analysed.
   - Total length of the tunnel and link road is about 9.092 km. Total project cost is about USD 674.91million, or equivalent to USD 74.23million per km.
   - The operation cost is estimated to be as BDT 171,620,000/year according to the price level in 2012.
   - The daily maintenance cost for traffic engineering (including tunnel electrical and mechanical equipment, road electrical and mechanical equipment, and traffic security facilities) is USD 1,800,000/year (price in July 2012), with inflation coefficient of 5%/year. Regular maintenance cost is USD 1,900,000 every five years (price in July 2012), with inflation coefficient of 5%/year.
6. The Environmental Impact Assessment is a legal requirement for obtaining Environmental Clearance Certificate from the Department of Environment (DoE) for implementation of proposed Multilane Tunnel Project at Patenga-KAFCO end under river Karnaphuli. The information and data presented in the report are based upon the preliminary tunnel design documents, and specific data obtained and gathered from relevant organizations/institutions, field survey and public consultation meetings in the study area in line with the Environmental Guidelines, (Volume 1) published by RHD as well as the EIA guidelines for industries published by DOE of the GoB.
   - The key impacts which were identified and addressed in the Environmental Impact Assessment report are land loss, involuntary resettlement, spoil waste, air and noise quality, disturbance during construction, construction pollution, management of the construction workforce and workers health and safety, management of accidents and emergencies.
   - As the proposed tunnel location is exposed to Bay of Bengal, there is possibility of tidal water flooding due to global warming and sea level rise. Climate change considerations will play a crucial role in the design of tunnel and its components.
   - Implementation of appropriate Environmental Management Plan (EMP) and mitigation measures during various phases will minimize the negative impacts of the Project to acceptable levels. To ensure that these plans and mitigation measures are implemented and negative impacts avoided, the EMP will be included in the contract documents of the Project with a separate line item on environmental management in the bills-of-quantities.

- Since the Project sponsor shows positive approach towards environmental management and safety standard more in-line with their environmental policy and management plan, it is expected that the BBA will provide necessary resources along with Safeguard Division like proper technical personnel with monitoring equipment to make accountable and responsible system for successful implementation of the recommended EMP recorded in the EIA Study.
- Necessary environmental clearance should be obtained for the project before start of construction work. As this EIA has prepared during feasibility study, this will be further updated during the detailed design stage based on the detailed engineering designs.
- All the potential environmental impacts have been reviewed, if the the recommended mitigative measures as per this Environment and Social Management Plan (ESMP) is strictly followed, the proposed Multilane Tunnel under the river Karnaphuli project is expected to proceed without having unacceptable environmental effects.

7. The proposed acquisition will eventually relocate households, commercial premises and common property resources for both titled and non-titled. The Resettlement Action Plan (RAP) covers compensation and assistance for resettlement and rehabilitation of Affected Persons (APs) including alternative sites, where feasible, for relocation of the housing, business structures and Common Property Resources (CPRs). Detailed RAP including disclosure and public consultation, relocation resettlement and income restoration, implementation arrangements, resettlement and compensation costs and budgets, RAP implementation schedule, grievance redress mechanism as well as monitoring and evaluation have been elaborated in the report.
8. The proposed land acquisition for the project will cause relocation of households, shops and common properties such as mosque, cremation ground, etc. which is very much sensitive and there is bar in acquisition of such common properties. The project authority should take care of these common properties and take mitigation measures during preparation of the land acquisition proposal as suggested in this document.
9. The tunnel project will be implemented under the Karnaphuli River and connect Chittagong City with planned development areas to the east. A range of social and economic benefits are expected to result from the tunnel including:
    - Better connectivity with the proposed industrial developments located east of the Karnaphuli River and the existing port, airport and CBD to the west;
    - Reduced congestion in the CBD and on existing bridges;
    - Shorter journey times and travel time savings;
    - Better utilisation of land east of the river for manufacturing generating additional value added contributions to the national economy as a result of better labour mobility, and the ability to efficiently move raw materials and completed products via the airport and port;
    - Direct connectivity with the New Deep Sea Port to be developed in Sonadia Island and catering to the additional traffic;

- Creation of synergies between the port and airport and existing and proposed tourism assets in Parkir Char east along the river and South Patenga west along the river;
- Improved emergency response in the East Area and the western sections of Patiya.

10. The preliminary findings of the financial analysis indicate that under the assumptions adopted, the tunnel, inclusive of toll revenues is not financially viable without government support. In summary, the key outcomes are:

    - **Without Financing Costs** - The funding gap under Option 1 (Public Sector Comparator exclusive of financing costs) is estimated at US$ 275 million.
    - **With Financing Costs** - Depending on the chosen financing option, the funding gap ranges from US$ 305 million to US$ 341 million.
    - **Interest Rate** - Sensitivity tests using higher interest rates shows the funding gap ranges from US$ 325 to US$ 661 depending on the financing option.
    - **Toll and Traffic Demand** - Sensitivity test around lower toll and traffic demand show that the funding gap ranges from US$ 349 to US$ 419 million depending on the financing option.
    - **Capital Cost Escalation** - Sensitivity tests around higher capital costs show the funding gap ranges between US$ 395 million to US$ 478 million depending on the financing option.
    - **Concession Period –** Sensitivity test around extending the concession period from 30 years to 40 years shows the funding gap ranges from US$ 183 million to US$ 246 million depending on the financing option.
    - **Soft Loan** – Sensitivity test around lower interest rates and longer repayment period provided by Donor Institutions show that the project is potentially financially viable under the financing option of 100% loan and at an interest rate of 5% or less with an extended repayment period.

    The Bangladesh Bridge Authority will need to seek ways to meet this funding gap. There are a number of options including:

    - A capital grant from the Bangladesh Government.
    - Seeking soft or concessionary loans from Donor Institutions with extended grace periods and favorable tenor conditions to minimize the debt service burden.
    - Using other incentive methods to entice potential investors such as land development rights.
    - Exploring other revenue streams such as indirect taxes.

    Each of these options could be considered individually however it is likely that a combination of options will be required to provide the best solution.

11. The project is anticipated to be divided into packages for construction such that it provides more opportunity for local contractors to be involved in contracts suitable for their skills and experience. Several procurement

strategies including Design Bid Build, Early Contractor Involvement and Design & Build have been proposed for different packages in the river tunnel project in order to optimise the speed, costs and quality of the tunnel. Guidelines for the tunnel during its operation stage and under emergency operations have been included in the Operation and Maintenance (O&M) Plan.