CHAPTER 9

SUMMARY OF NATURAL CONDITION SURVEY

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9.1 Maps and Aerial Photos

The maps and aerial photos collected through this Study are as follows:

(1) Topographic Maps

1) Land Use Map of Khulna City (Master Plan Area)
   May, 1988 by KDA Scale 1:10,000 11 sheets
2) Khulna Master Plan Area
   Scale 1 inch=330 ft. (1:3,960 by KDA)
   In 1968 ñ 1970, 6 sheets only in 32 sheets
   Note: These were revised in 1998.
3) Base Map: Rupsa, Digharia and Terakhada Thanas
   Scale 1:50,000 Local Government Engineering Department, 1993
4) Base Map: Jessore & Khulna Districts (No.79 F/5, F/9), 1977, 1976, Khulna District (No.79 F/6, F/11), 1969, 1973; Bagherhat & Khulna Districts (No.79 F/11) 1993. Scale: 1:50,000 Survey of Bangladesh
5) Map of the Khulna City Corporation Area
   Scale 1 cm = 0.115 km (1:11,500) by KCC

(2) Aerial Photos

1) Khulna Metropolitan Area
   IRS Panchromatic Image, 1998
   Scale 1:25,000 2 sheets
   By Environment GIS Support Project for Water Sector Planning
2) Satellite Images (Color) 3 sheets
   Scale 1:50,000 14 February , 1998
3) Satellite Image Mosaic (Monochrome)
   Scale 1:20,000 20 sheets
   Produced by Swedish Space Corporation
   Enlarged from 1:50,000 photos

9.2 Physical Conditions of the Study Area

9.2.1 Topography

Bangladesh is situated between 20 degrees 34 minutes ~ 26 degrees 38 minutes north latitude and 88 degrees 01 minutes ~ 92 degrees 41 minutes of east longitude. And the width is approximately 480 km in east and west and 680 km in north and south with the total area of 147,570 km^2. The great rivers such as Padma (Ganges) from the northwest, Jamuna from the north, and Meghna from the northeast are flowing through the country. And these great rivers confluence at the point 70 km west and 40 km south of Dhaka and flow into Bay of Bengal as the Meghna River. In Bangladesh, low and broad delta zones, namely the Brahmaputra-Jamuna Floodplain, Sylhet Basin and Ganges Delta, are formed through flooding of these great rivers and sedimentation of sand at river mouths. Fig. G-9.2.1.in Appendix G shows the Bangladesh Contours. The height of the land is about less than 50 m mostly, except some parts of the area in the northwest as bordering with India and some other areas in the east. The elevation of the Ganges Delta is about 15 to 20 m in the northwest and 1 to 2 m in the south. The project site is located in Khuluna, the largest town in the Ganges Delta, and the height of the project site is about 5 m. Natural levees and swampy hinterlands distribute at the project site.

9.2.2 Geology

Rock formations formed in Tertiary or older age are distributed only at the above-mentioned highland areas, namely the border areas with India and around Chittagong. Uplands formed in Pleistocene are distributed in the north-western and central part of the low land, and they are called the Barind and Madhupur Jungles. The remaining parts of the low lands consist of the Recent (Holocene) loose or soft alluvial deltatic or flood plain deposits underlain by more dense or stiff latest Pleistocene deposits.

The project site is located in Khulna, and the area along the river with Rupsa Bridge, Atherobaki Bridge and Atai Bridge is underlaid by the Recent tidal deltaic deposits composed by ebb and flow of the tide. In the north, the upper stream of Bhairab Bridge is deposited with the Recent deltaic silt, but a little older than the above-mentioned the tidal deposits. Fig. G-9.2.2 in Appendix G, is the Generalized Soil Map. As shown in that figure, the project site is covered by dark grey noncalcareous flood plain soils.

9.2.3 Climate

(1) Climate in Khulna City

The climate of Bangladesh is characterized by high temperature, much rain and high humidity. With the influence of the Himalaya Mountains, its temperature is relatively high as compared with other regions of the same latitude. It is located in the extreme north in the world as a region of moist tropics.

Table G-9.2.1 and Fig. G-9.2.3 in Appendix G show the climatic changes in Khulna City. The weather in Khulna is clearly divided into a dry season and a wet season like other cities in Bangladesh. Monsoon season starts in June and lasts into October. The mean annual rainfall is about 1,700 mm, and rains most heavily during June - August. About 80 % of the annual rainfall is recorded during this season and the average temperature is around 30°C causing humid days to continue. During November through May, rainfall falls to 5 mm – 100 mm with the temperature of about 20 °C making comfortable days.

(2) Regional Inspection Center in Khulna

Detailed weather data observed at Khulna RIC (Regional Inspection Center) for 1986-1995 including atmospheric pressure, temperature, rainfall, wind direction and velocity were obtained. Khulna R.I.C. under the control of the Ministry of Defense is located in about 500 m west of Khulna University, the suburb of Khulna City. R.I.C. undertakes meteorological observation for Khulna City in 24-hour system. There are 14 staff members at RIC working in three shifts of eight hours.

The observation items include atmospheric pressure, temperature, rainfall, wind direction and velocity, sunshine hours, and ground temperature below 5, 10, 20, 30 and 50 cm etc. The cloudiness of the sky is also recorded through naked eye observation from the roof to surrounding marks. Sunshine duration is recorded by a sunshine recorder.

Necessary equipment and machinery are installed in R.I.C. and observation are made 8 times in a day at 3-hour intervals both manually and automatically. Observed records are reported to Dhaka instantly by wireless in each 3 hours and processed through computers. Therefore, processed values are not filed in R.I.C. A R.I.C. is situated in each district totaling 64 places. The Khulna R.I.C. covers the entire Khulna district.

These meteorological data are compiled by the Meteorological Dept. in Dhaka and are provided in floppy diskets (MS-DOS: MS-Word) and also hard copy data. The data up to 1995 are compiled and provided as of September 1998. It takes about 2 weeks to obtain such data after making application. The weather data is available at the address shown in Table G-9.2.2 in Appendix G.

9.2.4 Hydrology

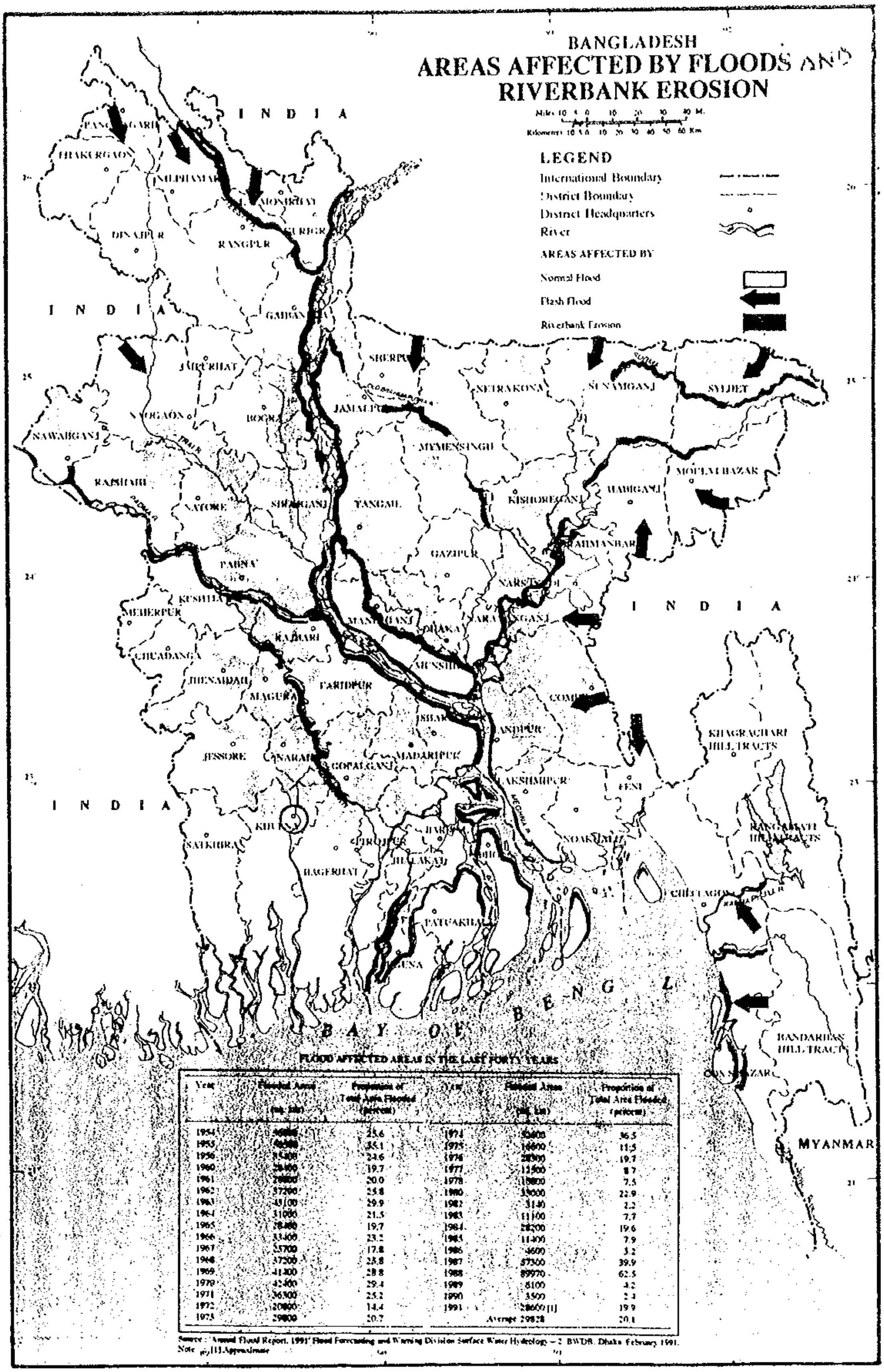
(1) River System

Bangladesh has three river systems, the Padma (Ganges) River, the Jamuna River, and the Meghna River. The Rupsha River and the Bhairab River runing in the project site are repeatedly merge and diverge at their upper stream and, through Jessore City, reach the Padma River near Kushtia City. The direct distance from the Khulna City to the Padam River is about 130 km.

There runs the Garai River as branched off from the Padma (Ganges) River at a point near the source of the Rupsa River. The name of Garai River is changed as the Madhumati River en route, and flows in the south-southeast direction and joins with other rivers at a point near Pirojpur City. The Garai River is one of those rivers which formed the immense delta zone as deposited with vast volume of sands through flooding, as the major river branched off with other rivers from Padma (Ganges) River in the 17th century. Even in these present days when the flow of the Padma (Ganges) River was moved to the east and the flow of the Garai River has become slow, the Garai River is still a major river as the branch of the Padma (Ganges) River. The Atai River, one of the study rivers, is also diverged from the Garai River and joined the Rupsa River at the eastern side of the project site.

(2) Areas Affected by Floods and Riverbank Erosion

Fig. 9.2.1 shows the areas affected by flood and riverbank erosion. The flash floods gushing out large volume of water and sands occur mainly in such high lands as those areas bordering with India. Most of the damages are caused by normal flood through



FLOOD AFFECTED AREAS IN THE LAST FORTY YEARS

Year	Flooded Area (sq. km)	Proportion of Total Area Flooded (percent)	Year	Flooded Area (sq. km)	Proportion of Total Area Flooded (percent)
1954	[illegible]	25.6	1974	52600	36.5
1955	[illegible]	35.1	1975	16600	11.5
1956	35400	24.6	1976	28300	19.7
1960	28400	19.7	1977	12500	8.7
1961	28800	20.0	1978	10800	7.5
1962	37200	25.8	1980	33000	22.9
1963	43100	29.9	1982	3140	2.2
1964	31000	21.5	1983	11100	7.7
1965	28400	19.7	1984	28200	19.6
1966	33400	23.2	1985	11400	7.9
1967	25700	17.8	1986	4600	3.2
1968	37200	25.8	1987	57300	39.9
1969	41400	28.8	1988	89970	62.5
1970	42400	29.4	1989	6100	4.2
1971	36300	25.2	1990	3500	2.4
1972	20800	14.4	1991	28600 [1]	19.9
1973	29800	20.7		Average 29828	20.1

Source : 'Annual Flood Report, 1991' Flood Forecasting and Warning Division Surface Water Hydrology – 2 BWDB, Dhaka February 1991.
Note : [1] Approximate

Source : Mott MacDonald, Cambridge, England.

Fig. 9.2.1 Areas Affected by Flood and Riverbank Erosion in Bangladesh
(Graphosman World Atlas, 1996)

rising of water level. Most parts of the study area are those flood areas, except for Khulna City. Many riverbank erosion cases are recorded along the great rivers. In the Padma (Ganges) River, the right side bank is eroded. Along the rivers near the project site, the damage by erosion were recorded for the embankment of the Garai River and Madhumati River. The damaged length is calculated as about 120 km in the drawings, and this length starts at the point near the diverging point from the Padma (Ganges) River and reaches near Khulna City. In this figure, no riverbank erosion was recorded at the project site of the Rupsa River.

(3) Cyclone

Cyclones in the Bay of Bengal occurs mainly during two seasons, April – May and October – November. The cyclones of October-November period are in many cases destructive and powerful. Khulna City was attacked by cyclones for 11 times between 1960 and 1993, almost once in 3 years, as described in Table 9.2.1.

Table 9.2.1 Frequency of Cyclones Attacking Khulna

May	1991, 1960, 1977	October	1967, 1969, 1970, 1985
August	1974	November	1901, 1988
September	1978		

When a heavy cyclone attacked Khulna City in November 1988, a wind velocity of 160 km/h (44m/sec) and wave of 14.5 ft. high at Mongla Point were recorded (Statistical Year Book of Bangladesh, 1996). Table G-9.2.3 in Appendix G shows the major cyclones that attacked Bangladesh in last 32 years from 1960 to 1991. As shown in Fig. G-9.2.4 in Appendix G, most of the cyclones, that attack Khulna have come from the Bay of Bengal in south-southwest – north-northeast/northeast direction.

9.2.5 Earthquake

Bangladesh is located in the Bengal Basin which is the very active area of earthquake in the world. The earliest earthquake record in Bangladesh is in 1664. The epicenter of this earthquake was Dhaka. There were seven major earthquakes, attacked Bangladesh in these 150 years. The Cachar Earthquake in January 1869 recorded a magnitude 7.5 causing serious damage in Sylhet. In July 1918, the Srimangal Earthquake occurred and, the Assam Earthquake attacked Assam in August 1950 recording a magnitude of 8.5. Most of these earthquakes occurred in the northeastern part of Bangladesh and in India. In Bangladesh, the Geological Survey of Bangladesh and other bodies set up the Committee of Experts on

Earthquake Hazard Minimization and issued a report in November 1979 as titled "Seismic Zoning Map of Bangladesh and Outline of Code for Earthquake Resistant Design of Structure". This Zoning Map classified Bangladesh as Zone I, Zone II, and Zone III and indicated 0.08, 0,05, and 0.04 respectively as basic seismic coefficient. According to this zoning, Khulna area belongs to Zone III whose basic seismic coefficient is 0.04.

In addition, there is another Seismic Zone Map, prepared by Meteorological Department as shown in Fig. G-9.2.5 in Appendix G and Table 9.2.2. It classifies Bangladesh into Zone I, II, III and IV with their respective seismic factors as 0.2~0.1g, 0.1~0.07g, 0.07~0.05g and less than 0.05g (g:1,000 cm/sec^2), which established larger seismic acceleration than the seismic coefficient provided by the Geological Survey of Bangladesh. Based on these Figure and Table, the seismic coefficient of Khunla is estimated as 0.05g. Thus, Khulna belongs to the zone of which seismic coefficient is the smallest in Bangladesh.

Table 9.2.2 Seismic Zones of Bangladesh

Zone	Scale	Seismic Factor	Area
ZONE I	Major & Damaging	1/5 to 1/10g	The north and north-eastern parts including. The towns of Sylhet, Mymensingh and Rangpur.
ZONE II	Moderate	1/10 to 1/15g	Dinajpur, Bogra, Tangail, Dhaka, Co milla and Chittagong Hill tracts.
ZONE III	Minor	1/15 to 1/20g	Rajshahi, Pabna, Faridpur, Noakhali Chittagong and Cox's Bazar
ZONE IV	Negligible	1/20 or less	The souse-western parts of Bangladesh including Jessor, Khulna, Barisal and Patuakhali.

9.3 Soil Investigation

9.3.1 Topography and Soil of the Area Investigated

The area investigated is in the Khulna city region which is located in the drainage basin of the tributaries of the Padma river (The Ganges river), namely, the Bhairab river, the Atai river, the Rupsa river and others, and is positioned in the vicinity of the tip of alluvial fan of the deltaic zone called the Ganges Delta, and is forming a part of the Bengal Lowland with the height of around 5 m above sea level.

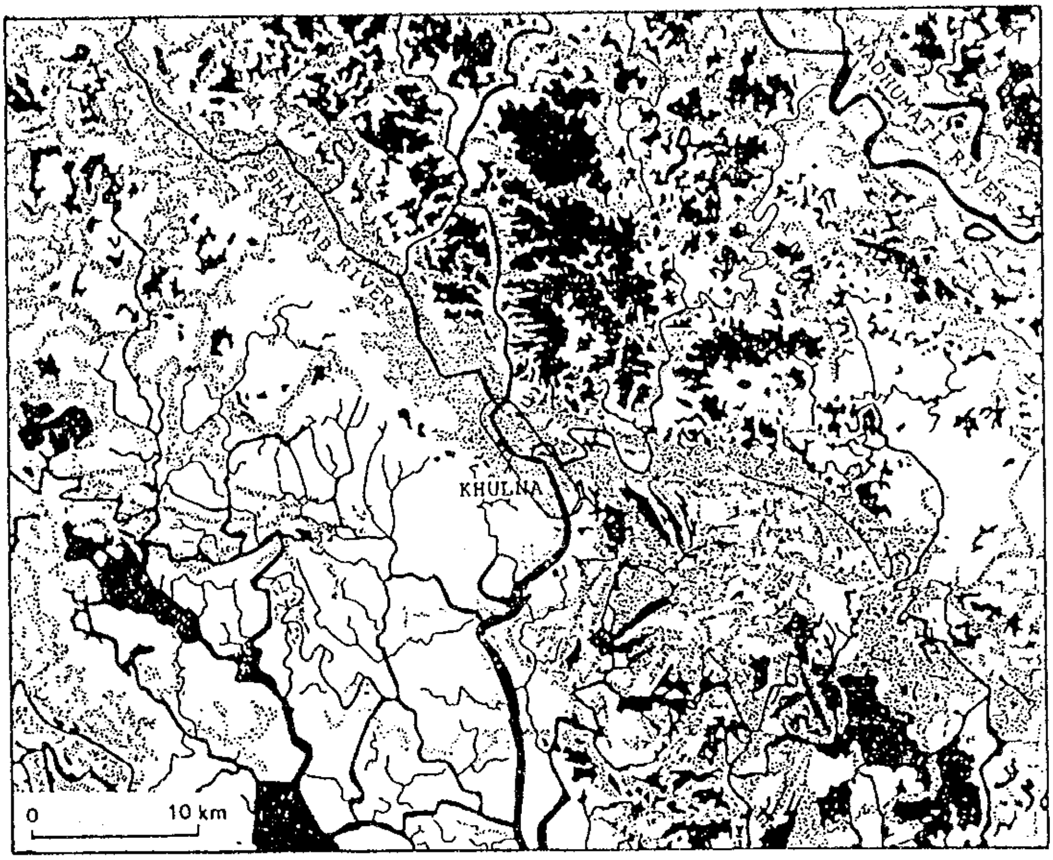
Landform Classification Map of Khulna Region is attached as Fig. 9.3.1. to show the landform classification in the city region of Khulna. As seen from this map, the topography of the Khulna city region consists of natural levees evolved along the rivers Bhairab and others with higher elevation, and low-lying backswamps of wet and poor drainage, which expand behind these levees. In detail, the natural levee is showing tendency of evolving toward the direction of Mongla road after bending in the eastern direction around the Rupsa Ferry, and is evolved less from the point of Rupsa Ferry and along the south side of the Rupsa river while backswamps are expanded from there into the entire area.

Soils distributed in the area are the recent deltatic or flood plain soils and mainly consist of sandy and silty soils in grayish and dark gray colors. Also, peat soils are distributed in some localities. Natural levees consist mainly of sand and coarse grained silt while backswamps consist of fine-grained silt.

9.3.2 Topography of River Banks in the Vicinity of Bridge Sites

(1) Rupsa Bridge Site (Rupsa river)

Topography of the riverbanks at each proposed bridge site was observed using a boat. In the vicinity of proposed bridge site on the Rupsa river - Alignment A, there are embankments with the height of 3m and width of 3 - 5m, constructed on both banks of the river. Several small collapses, due to erosion by the river flow, are observed on the slope of the left bank embankments. Erosion seems occurring more on the left bank side (Mongla side) rather than on the right bank side.



Landform classification map of Khulna region.

1. Broad and obscure natural levees 2. Normal natural levees (including broad and distinct natural levees, small and continuous natural levees) 3. Backswamps 4. Swampy lands (including swampy backswamps and abandoned river channels) 5. water surfaces.

Fig. 9.3.1 Landform Classification Map of Khulna Region

(UMITSU; Natural Levees and Landform Evolutions in the Bengal Lowland, Geographical Review of Japan, 1985)

The embankments are constructed with silty and clayey materials and paved with bricks on its crest and used as road. There are some sections of the embankments on the left bank side which were eroded on its slope and the embankment has become thin and, thereby, bricks on the road have fallen into the river. There are traces of collapses as observed on the crest of levee at few places within a stretch of 500m up-stream of the proposed bridge site. These are being treated temporarily by earth-filling works. Some rehabilitation works on the sluices and other facilities have been carried out.

Houses on the right bank side are mainly distributed in a narrow area located along the embankment with some number of houses scattered in the backswamps through which an approach road of the Rupsa Bridge has been planned. On the left bank side, there are only very few number of houses located along the embankment and no houses at all being observed in the backswamps. At the time of this investigation, during the months of August and September 1998, inundation with 30 - 50 cm deep water was observed in the backswamps area. When the tide is rising, water level of the river rises higher than the land level inside of the embankment by few meters. It was observed on the left bank side, at several places during the high tide period, that river water was gushing out into the lowland behind the embankment through defective sluice gates.

On the right bank side, the investigation sides are accessible by car. However, the sites on the left bank side are not accessible by car as the width of the embankment for a stretch of 500m up-stream of proposed Rupsa Bridge Site was lost by the river erosion. It was passable only by foot and it was approximately 2.5km in distance from here to the Rupsa Ferry Ghat.

(2) Atherobaki Bridge Site (Atherobaki river)

The Atherobaki river joins the Rupsa river at a point approximately 2.3km up-stream of Rupsa Ferry Ghat.

Atherobaki Bridge Site is planned to be located at a point approximately 3.5km up-stream from this point of confluence The Atherobaki river merges with the Rupsa river after repeated meandering, and the proposed bridge site is located at the point where the Atherobaki river meanders as a large U shape. As regard the trace of collapses due to erosion on the river banks, it was observed slightly more on the right bank side rather than on the left bank side where the bank slope appears with smoother surface. Although, the left bank side is on the slope of attack, it is observed that the erosion takes place less frequently and smooth slope surface is maintained more frequently. It is that, in general the collapsed slopes are situated on the foundation of fine sandy material, in general.

In the vicinity of an approach road to the proposed bridge, there exists a brick field on the right bank side and an agricultural land with flood water depth of few meters and a cluster of housings further down on the left bank side.

(3) Atai Bridge Site (Atai river)

The up-stream portion from the point of confluence of the two rivers, Rupsa and Atherobaki, is called the Bhairab river in accordance with the Topographical Map of 1/10,000, produced by K.D.A. Approximately 4 km upstream to the north of this point is located another confluence point of the Bhairab river and the Atai river. The proposed Atai Bridge Site is located further 800 m upstream in the Atai river.

Topography on the river banks of the Atai river from the junction point to the proposed bridge site, in general, is showing many embankment collapses on the right bank side while slightly smoother topography is appearing on the left bank side with an exception of the area in the vicinity of the junction point. The area in the vicinity of the junction point is eroded in general. Soil from the surface of the right bank side was observed as silt with comparatively less cohesion.

There is a slight difference in the topography as shown on the topographical map of scale 1/50,000 produced in 1976 and the topography as shown on the recent aerial photo. The configuration of the rivers as shown on the old 1/50,000 map is with angular and straight lines while the same river configuration with roundness in the aerial photo.

The left bank side of the area is inundated by the river water due to high tide, making the whole investigated area to appear as a retarding basin. The entire area with an exception of a part of the embankment went under water during the study period.

(4) Bhairab Bridge Site (Bhairab river)

The Bhairab Bridge Site is located at a point some 10.5 km further up-stream of the confluence point of Atai river and Bhairab river. On the island side of the left bank of the Bhairab river, some collapsed topography accompanied with terraces are continually observed at some portion, while on the right bank side (Khulna city side) of the river, there is no collapse and comparatively smooth bank surfaces are observed continuously. As it is reaching the proposed bridge site, a smooth topography on both side of the river bank was observed.

On the left bank side of the Bhairab river, houses are scattered to the edge of the bank. These houses are inundated up to the height of floor almost every time when the river water level rises and become like small islands.

9.3.3 Boring Investigation

(1) Outline of the Investigation

The boring investigation was conducted to a depth of 32.5 - 48m at the proposed three bridge sites. As for the in-situ test, the standard penetration tests (SPT) were conducted at 1.5 m intervals in the boreholes. The laboratory soil tests were carried out using the samples obtained by these SPTs. Table 9.3.1 shows the quantities of the works performed.

Table 9.3.1 Boring Investigation and Soil Tests

Name of Bridge	Name of the River (Location of Boring)	Depth of Boring (m)	Kind of Tests		
			SPT (Nos.)	Laboratory Soil Tests (Nos.)	
Atherobaki Bridge	Atherobaki River (On the crest of left bank embankment)	48.5	32	Grading Analysis Moisture Content Specific Gravity of Soil Particle Liquid and Plastic Limits	12 12 3 2
Atai Bridge	Atai River (On the crest of right bank embankment)	39.5	26	Grading Analysis Moisture Content Specific Gravity of Soil Particle Liquid and Plastic Limits	11 11 3 5
Bhairab Bridge	Bhairab River (On the right side river bank)	32.0	21	Grading Analysis Moisture Content Specific Gravity of Soil Particle Liquid and Plastic Limits	10 10 3 2

All of these investigations and tests were conducted in conformity with the standards of ASTM. In order to secure an accuracy of the investigations, necessary measuring, weighing and confirmations were conducted prior to start of the investigations on the weight and falling height of SPT hammer, length of rod to be used, etc.

Precise locations of borings were selected on the center lines between the lines of center line survey and bathymetric survey of either on the right bank or on the left bank of each proposed bridge sites

Results of boring and SPT N-values were summarized in drilling logs and annexed hereto in Appendix G.

(2) Results of Investigation

The boring investigation was carried out first at Bhairab bridge site located in up-stream (North side), followed by the Atai bridge site and Atherobaki bridge site located in down-stream (South side).

Results of the investigation revealed that the each site is covered by very soft to soft silty soils with SPT N-value of 1 to 4. Thickness of these silty soils varies from 4.5 m at the Bhairab bridge site to 17.0 m at the Atai bridge site.

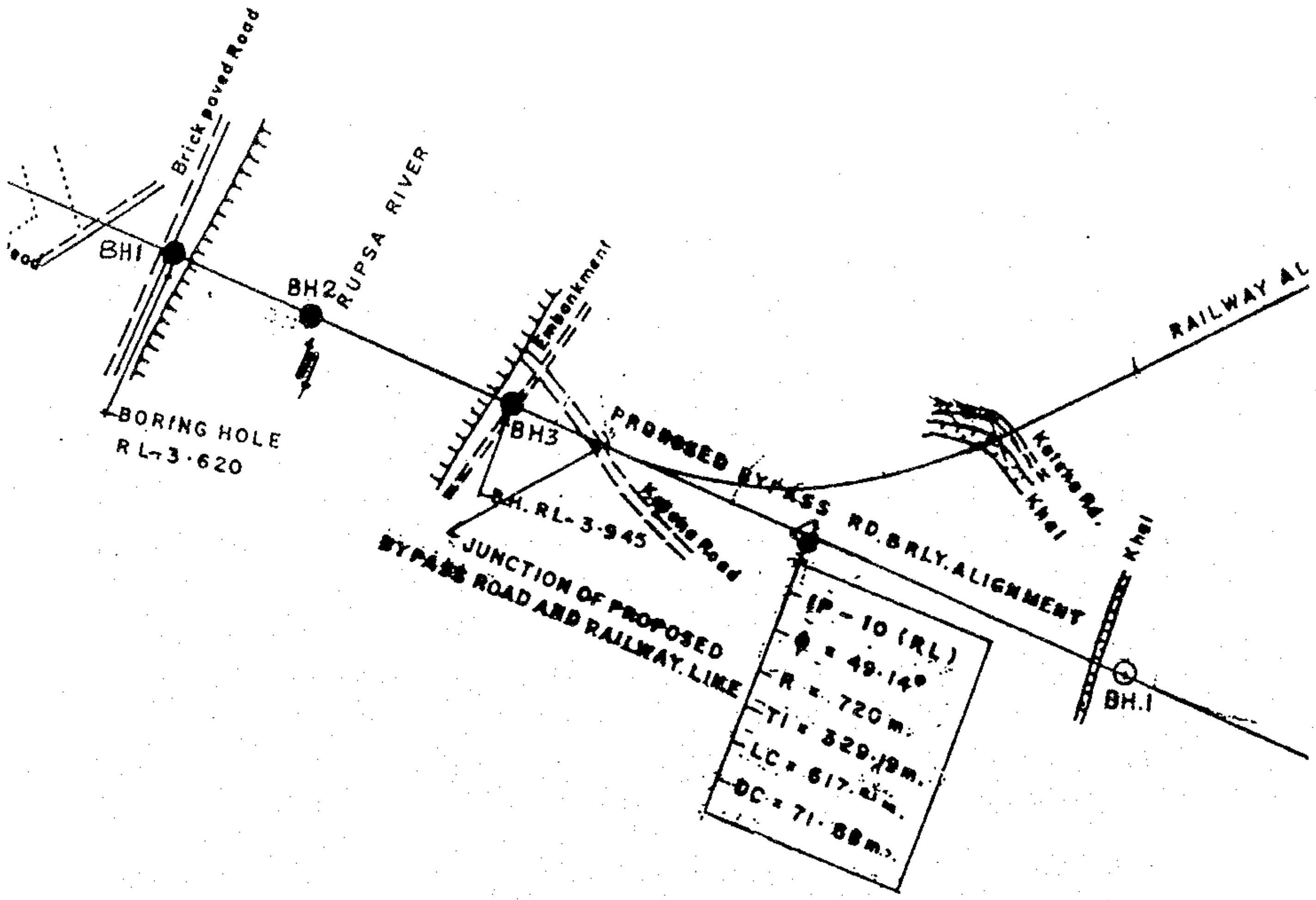
A medium dense sand layer with SPT N-value of an order of 20 was encountered below the above-mentioned silty soils at the Bhairab bridge site. At this site, from the depth of 18 meters, relative density of sand layer is changed to very dense to dense states with SPT N-value exceeding 45. In comparing the drilling logs of this Bhairab bridge site to that of the Rupsa bridge site prepared in the ADB project, it is estimated that the dense to very dense sand layer between the two sites have a certain continuity because of the features common to the both layers such as the shape of SPT N-value curvatures and a massive content of mica fragments. The Bhairab bridge site is showing, however, about 10 m shallower than that of the Rupsa bridge site in the depth of distribution of very dense to dense sand layer.

On the other hand, at the Atai bridge and Atherobaki bridge sites, it was confirmed that a thicker layer consisting of very soft to soft slity soils and relatively less compacted sandy soils overlays sandy layers of which SPT N-values increase with depth. A very dense sand layer with SPT N-values of 50 or more was not encountered within the explored depths, 39.5 m at the Atai bridge site and 48.5 m at the Atherobaki bridge site. However, from the vicinity of 30 m in the depth, it was confirmed that there is a dense sandy soil layer with SPT N-value of more or less of 35. The SPT N-values of this layer at the Atherobaki bridge site are slightly higher than those at the Atai bridge site. Higher silt and clay content in soils at the Atai bridge site may cause this difference. The sandy layer distributed in this depth is estimated to be of similarly compacted sandy layers which are distributed at Bhairab bridge site from the features of the layers such as its color and the content of mica fragments, etc.

(3) Drilling Log Map

Fig. 9.3.2 shows the site location map of boreholes at Rupsa Bridge site conducted by ADB. Figs. G-9.3.1 (1) – (8) in Appendix G are the drilling log maps of BH-1, BH-2 and BH-3 at Rupsa Bridge site.

The drilling log maps of Atherobaki, Atai and Bhairab Bridge are indicated in Figs. G-9.3.2 – Fig. G-9.3.4 in Appendix G.



SITE PLAN SHOWING LOCATION OF BOREHOLES
BRIDGE OVER RUPSHA RIVER

Fig. 9.3.2 Location of Boreholes at Rupsa Bridge Site

9.4 Topographic Survey

9.4.1 Center Line Survey

(1) Placement of Center Stakes

The center line survey was carried out on the outside of the river banks of each proposed bridge site for the distances as enumerated below, and the Longitudinal Survey was conducted at an interval of 20 m on this center line to define the configuration of the topography. The results of these surveys are compiled together with the result of batymetric survey and annexed hereto in Appendix G.

The survey stakes made of wood were driven and placed on the starting point and the terminal point of each survey line and on the crest of the embankment. (where the starting point and the terminal point were submerged under water, then, the nearest survey stations of which were not submerged under water were substituted. The distances surveyed for each bridge are as follows:

①	Rupsa Bridge:	700 m (350 m each on the right bank side and the left bank side)
②	Atherobaki Bridge:	200 m (100 m each on the right bank side and the left bank side)
③	Atai Bridge:	200 m m (100 m each on the right bank side and the left bank side)
④	Bhairab Bridge:	200 m m (100 m each on the right bank side and the left bank side)

(2) Placement of Temporary Bench Mark (TBM)

In the present investigation, as detailed in Table G-9.4.1 in Appendix G, temporary bench marks (TBM) are installed in the vicinity of river banks of both sides of the each proposed bridge site. The TBMs were placed by marking on a selected foundation of a solid structure located as near as possible to the proposed site. For Rupsa Bridge Site, an existing bench mark was available and was used for the purpose.

For installing the above TBMs, the location and the level of the existing bench marks in the city of Khulna shown in Table G-9.4.2 in Appendix G, were checked at the Khulna Office of the Bangladesh Water Development Board (BWDB) and their levels expressed in feet were converted into meter and used for the present survey. The existing bench marks are made of solid concrete column with the size of 20 cm x 20 cm and bearing metal rivet on its top. These bench marks were placed in 1967 and were used for level surveying ever since and are still existing and used as bench marks as are.

At the proposed Rupsa Bridge site, there exists three (3) TBMs (Temporary Bench Marks) placed by Roads and Highways Department (RHD), two (2) on the right bank embankment and one (1) on the left bank embankment. These TBMs are made of concrete with the width of 35 cm x 35 cm and the height of 17 cm x 27 cm. The levels of these bench marks are given on these bench mark posts and their values are given in Table 9.4.1.

Table 9.4.1 Levels of Existing TBMs at Rupsa River

Right Bank Side	TBM = 4.380 m (Up-stream side)
	TBM = 4.460 m (Down-stream side)
Left Bank Side	TBM = 2.584 m

9.4.2 Bathymetric Survey

Bathymetric survey was conducted for the direction of crossing the river at each proposed bridge site. Actual survey was done by setting a theodolite on the center line on the embankment and focus it on the direction of the center line on the opposite side embankment. Then, a boat loaded with an echo-sounder was guided from the land and was moved across the river measuring the depth from water surface to the bottom of the river at an interval of 10 m.

Horizontal position of the boat on the direction of crossing the river was measured by catching signals from the satellite on GPS antenna loaded on the boat. At the same time, the digital information obtained from the echo-sounder was processed by and recorded on computer.

This bathymetric survey was conducted by selecting the time of slack water (due to turn of tide) as velocity of the river discharge become low and boat operation become easier. An approximate distances between the shoulders of the slopes of the embankments of each river and the distances of the bathymetric survey lines are as shown in the Table 9.4.2 below: With an exception of the Rupsa Bridge site, the topography of the river banks are all uneven and variable surfaces and the water level of the river is also goes up and down frequently, which makes it difficult to obtain an average width of the river in the strict sense of the word. It is, therefore, expressed here that the distances between the embankments or the river banks on the survey lines as remained on the water surface at the time of full water level of the river.

Table 9.4.2 An Approximate Distance Between the Shoulders of the Slope of the Embankment and/or the River Bank

① Rupsa Bridge	:	586 m	(583 m)	Distance between the slope of the embankments
② Atherobaki Bridge	:	312 m	(306 m)	Distance between the river banks
③ Atai Bridge	:	281 m	(275 m)	Distance between the river banks
④ Bhairab Bridge	:	283 m	(283 m)	Distance between the river banks

Note: Figures in parenthesis are the distances on the water surface as obtained by the batheymetric surveys.

Figure. G-9.4.1 in Appendix G, is showing a cross section of the rivers at each proposed bridge site.

Maximum depth from the water surface to the bottom of the river at the time of this survey at each proposed bridge site is as indicated in the Table 9.4.3 below: These figures of batheymetric Surveys have been converted to PWD Standard for Elevations and have been used together with the results of the Center Line Survey for preparation of the River Profile at present

Table 9.4.3 Maximum Depth of Water at the Time of Survey

① Rupsa Bridge	:	13.2 m	(PWD 3.615 m)
② Atherobaki Bridge	:	9.3 m	(PWD 3.050 m)
③ Atai Bridge	:	12.8 m	(PWD 1.309 m)
④ Bhairab Bridge	:	6.7 m	(PWD 3.323 m)

Note: Figures in parenthesis are water level in elevation at the time of the batheymetric survey.

9.5. Hydrological Investigations

9.5.1 Water Level of the Rivers

(1) Collection of the Record of Observations

Water level of the rivers in Bangladesh have been observed and recorded all the time by the BWDB (Bangladesh Water Development Board). The Khulna water level gauging station is located close to the ferry station called the Jail Ghat which is almost in the center of the Khulna city.

This gauging station is called [Khulna 241] and has been gauging the water level of the Rupsa river continuously since 1937 by means of manual as well as automatic recorders.

This gauging station is installed at about 10 m inside of the Rupsa river from its river bank and is made of steel cylinder with red color painted on the outside and contains an automatic water-gauge for 1- week recording. At the same time, a meter staff is attached on its outside for readings of water levels visually, 5 times a day (at hours of 6:00, 9:00, 12:00, 15:00 and 18:00) and day-highest and day-lowest every day. These readings are recorded together with the record of automatic water-gauge and reported to Dhaka once every 7 days for statistical processing.

In addition to this gauging of the water level of the river, BWDB has an observatory for precipitation within the city of Khulna which is called [Khulna: R510]. Further, the salinity of the river water is being observed separately by BWDB as well. The Hydrological Network is shown on Fig. G-9.5.1 in Appendix G.

The records of observations are electronically processed and kept in custody and made available and publicized on demand. However, in September 1998, only the records up to 1996 were made available. It may be made available of the records thereafter from the source shown in Table G-9.5.1 in Appendix G.

(2) River Water Level and Others

Water levels centered on Khulna 241 and its vicinity and the daily data of precipitation have been collected. However, the data on salinity were not made available due to some trouble on computer system of BWDB.

The variation of water level of the Rupsa river during one year period from April 1, 1994 to March 30, 1995 as gauged at Khulna 241 are shown in the Fig. 9.5.1. Water level of the Rupsa river begins to rise in the month of May and it reaches a peak from the beginning of the month of July to the end of August. It starts to descend in the month of September and reaches its lowest in the months of January and February. As shown in Fig. 9.5.1, the maximum value of water level in elevation is 3.22 m (PWD) and the minimum value is -0.73 m (PWD), showing the difference in water level elevations of nearly 4.0 m. The difference in between the highest water level and the lowest water level in a day is 3.2 m at maximum and 1.3 m at minimum and, therefore, the difference in average of water levels in the day is calculated as 2.2 m. The highest high water level recorded at Khulna 241 station from April 1968 to March 1996 is 3.41 m (PWD) in 1989.

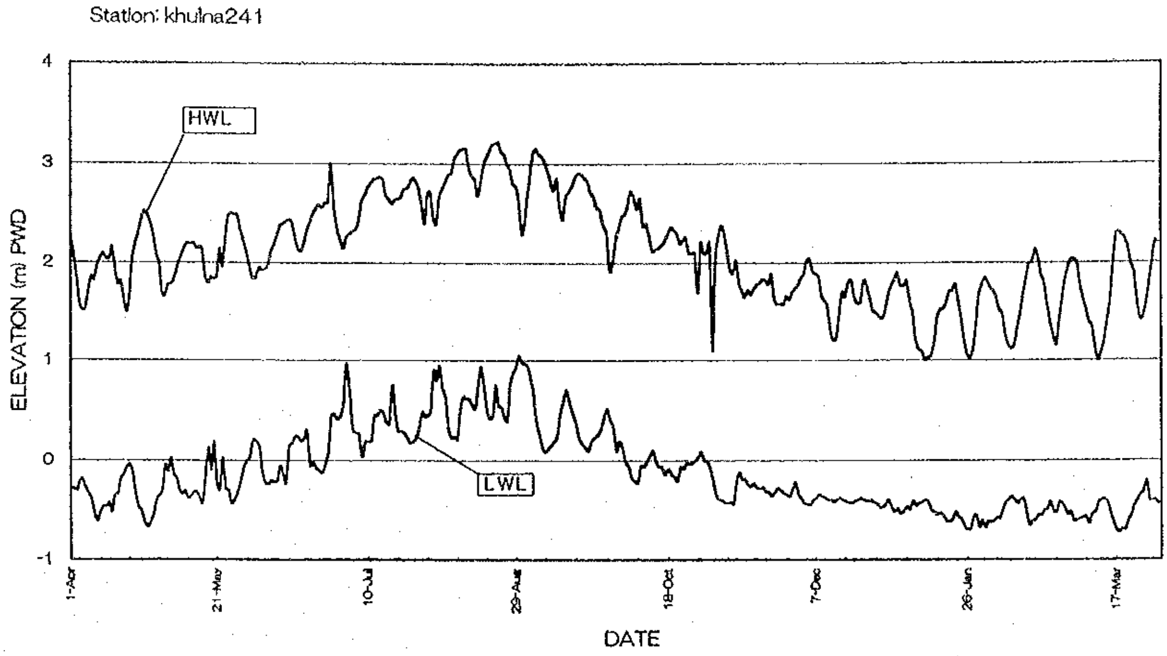


Fig. 9.5.1 Water Level Variations of the Rupsa River at Khulna (1994-1995)

Regarding the water salinity of the Rupsa river, the results of observations are recorded annually on the Year Book which indicates a rising trend in general as shown in Fig. 9.5.2. According to this record, the salinity exceeding 20,000 micro-mhos is observed in the year 1996, which is more or less equal to that of sea water.

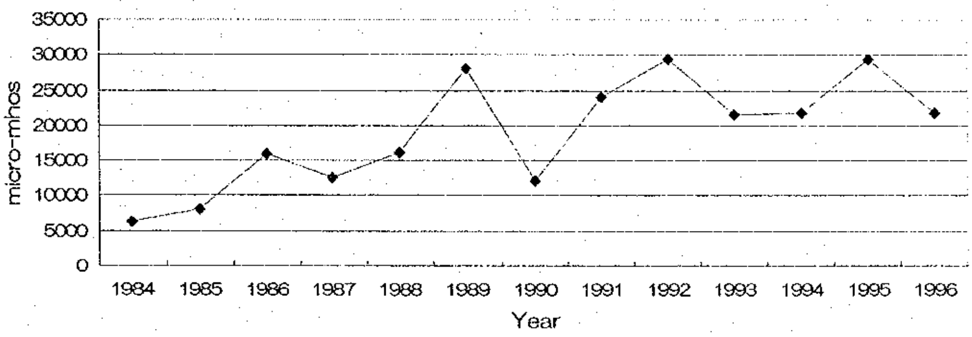


Fig. 9.6.2 Salinity at Khulna 241 Station

(Source: Statistical Yearbook of Bangladesh, 1996)

9.5.2 River Bed Elevation

Configuration of the river bed at each proposed bridge site has been confirmed by the results of batheymetric survey for the river cross sections. The elevations of the deepest river bed at each proposed bridge site thus obtained based on the results of the batheymetric survey are enumerated in the Table 9.5.1: The lowest elevation of the river bed is found at -11.49 m at the Atai Bridge site and next comes at - 9.59 m at the Rupsa Bridge site.

Table 9.5.1 Elevations of the Deepest River Bed

Proposed Bridge Site	Approx. Width (m)	Elevation (PWD) m	Features of River Bed Configuration
Rupsa Bridge	586	-9.59	River depth gets deeper from the center of the river toward the Mongla side.
Atherobaki Bridge	312	-6.25	River depth is deeper in the vicinity of 50m from the left bank side.
Atai Bridge	281	-11.49	River depth gets deeper from the center of the river toward the left bank side.
Bhairab Bridge	283	-3.38	Nearly flat configuration all over the river bed.

9.5.3 River Current Velocity

(1) Method of Measuring

A marking with red and white color is set on both river banks at an interval of 100 m centering on the batheymetric survey line and establish the river current velocity measuring sections are established. Then, a float is thrown into the river on the upstream side of the measuring section and the time that float takes to flow down the 100 m section is measured using a stop watch.

The Rupsa river where width of the river is fairly wide is divided equally into eleven (11) sections and three (3) other rivers of Atherobaki, Atai and Bhairab where width of the river is comparatively narrow are divided equally into six (6) sections and the current velocity around the survey line is measured respectively. Measuring of the current velocity was conducted for both up-ward flows and down-ward flows on the Rupsa river which is located most downstream side. On three other rivers of Atherobaki, Atai and Bhairab which are located on upstream side, only downward flow is measured. Timing of the measuring of velocity was selected in the time zones when the river current velocity reaches a dayís maximum.

(2) Results of the Measurement

The results of the measurement of current velocity of each river are shown in Table G-9.5.2 in Appendix G and Fig. 9.5.3. A maximum value of the river current velocity, recorded on or around the center of the Rupsa river was 2.38 m/sec. A maximum velocity of 2.25 m/sec was recorded at 120 m point on the Atai river. It was confirmed that the rivers with higher velocity are Rupsa river and the Atai river. Further, measuring of the current was done on the

Rupsa river during the time of high tide, but because it was in the monsoon season that river discharge was so great from the upstream on the Rupsa river that there was not any occurrence of up-ward flows from downstream to upstream during the time of high tide.

9.5.4 Riverbed Shift

It is an essential factor to be taken into account in planning the bridge location, length and revetments that whether a part of the river in consideration has been historically shifted to some extent and then there may be possibility of similar movement in the future.

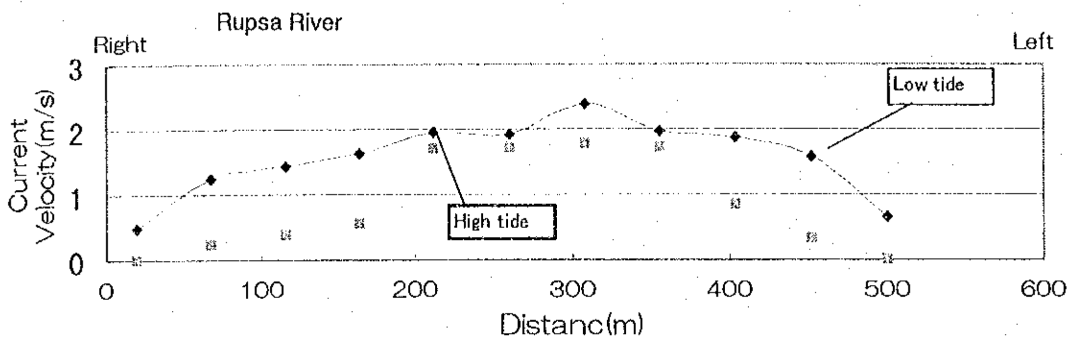
The Surface Water Modelling Centre in Bangladesh conducted a study on riverbed shift of the rivers near Khulna, which is very helpful to the Project. The study was made by laying a satellite image taken in 1990 over a map surveyed by SOB in 1973. Fig. 9.5.4 indicates the map of riverbed shift near Khulna. Comparing these two, shifts of the riverbeds are clearly observed and the following facts were found;

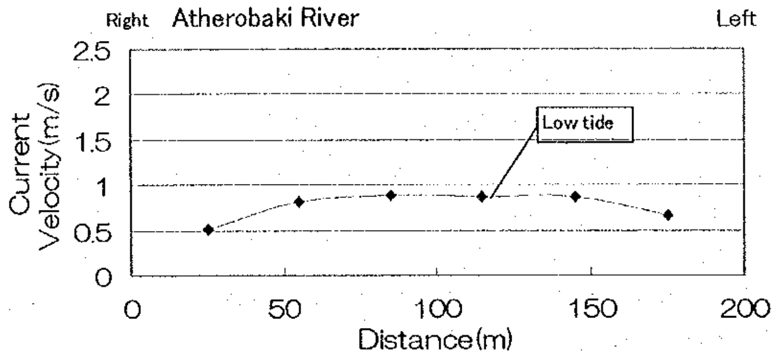
- The confluence point of the Bhairab and Atai River has moved approximately by 500 meters southward during the period.

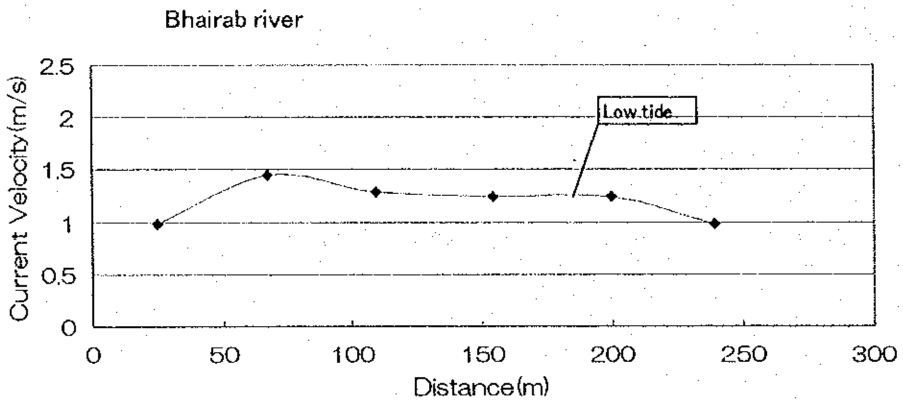
- Regarding the Atherobaki River, the bottom of U-shape has shifted by 100 meters southward.

- The Rupsa River has shifted eastward by almost 100 meters near the Ferry and upstream of it, and also become less wide around the Shipyard and downstream part of it.

- Unfortunately the site of Bhairab Bridge is out of the study area, and then no information can be obtained from the riverbed shift map.







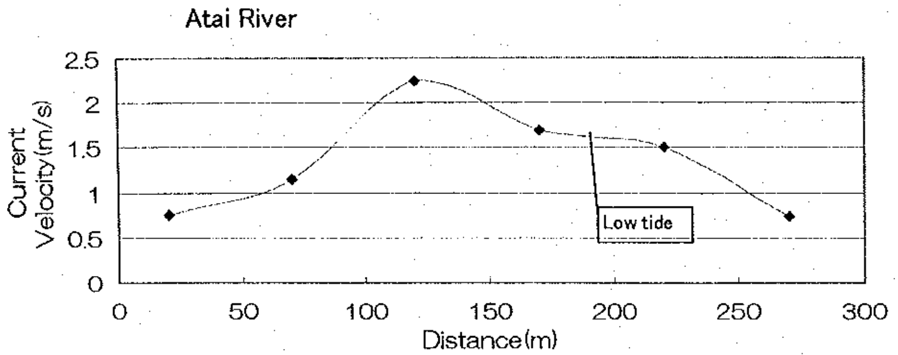


Fig. 9.5.3 Results of Current Velocity Measurement

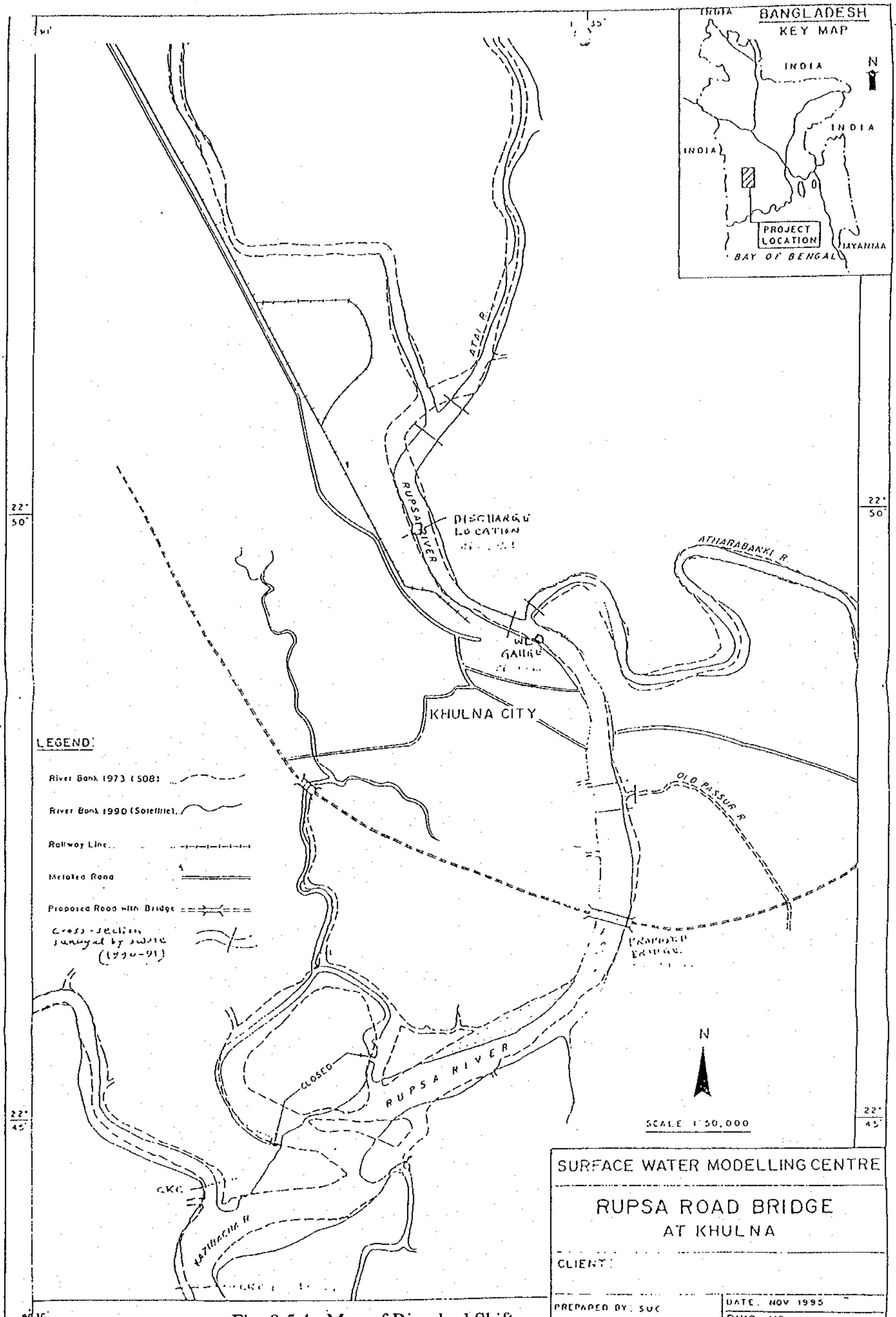


Fig. 9.5.4 Map of Riverbed Shift

CHAPTER 10

PLANNING PARAMETERS AND DESIGN CRITERIA

CHAPTER 10 PLANNING PARAMETERS AND DESIGN CRITERIA

This chapter is prepared to reveal planning parameters and proposed design criteria for the Bridge supported by engineering considerations. Planning parameters for port and railway are discussed respectively in relevant chapters, and they interweave their recognition of status quo and demand forecast.

10.1 Planning Parameters

Planning Parameters are required to be studied for the deliberation upon major issues, which have been encompassing the Bridge from technical, social, managerial, economical and financial viewpoints.

On the other hand, preparation of design criteria is to be studied for preliminary design, based on construction plan and cost estimates standards or criteria customarily applied in Bangladesh.

10.1.1 Scheme of Khulna Bypass, Road or Road Parallel to Railway

(1) Scheme of Khulna Bypass

Mongla Port Area Development Project (MPADP) was studied based on the assumption that Railway Extension to Mongla Port should run parallel to Khulna Bypass and existing Khulna - Mongla Road. Accordingly, Rupsa Bridge has been studied, taking into account scheme of rail-cum-road bridge.

However, no justification is found that such assumption might be essential and crucial to examine the possibility of the extension plan.

In the Study, the scheme of Khulna Bypass is to be studied for route location and configuration of road itself from the viewpoints of road planning and highway engineering in both the eastern and the western sides of the river.

(2) Railway Extension to Mongla Port

In the Study, the scheme of Railway Extension to Mongla Port is assumed to connect existing railway to Mongla Port only to accommodate future cargo demand, and such future demand will be examined whether it enables to sustain railway operation in terms of economically, financially and managerially viable. The scheme of rail-cum-road bridge may be one of alternatives to enhance possibility of the extension plan by reducing construction costs.

10.1.2 Cross Sectional Configuration

Generally, cross sectional configuration of road mainly depends on the location where it is planned in urban or rural, to say nothing of number of lane based on traffic demand. It is commonly aware that urban road has sidewalk, cycle track, frontage road with buffer zone in addition to through traveled lanes with shoulders.

Khulna-Mongla Road is designated rural arterial road to connect regional/district centers such as Mongla International Port and Khulna the third largest city in Bangladesh, while Khulna Bypass proposed by Khulna Development Master Plan is designated urban arterial road to strengthen road network in Khulna city and its surroundings.

Rupsa Bridge on which Khulna Bypass is located in the western side of the Rupsa river is to have one of expected roles and functions to be substituted for Rupsa Ferry, in which commuter traffic is found major users and non-motorized vehicles are also potentially dominant. Accordingly, the Bridge is regarded as a city bridge in urban area, namely cross sectional configuration comprising through traveled lanes with shoulder plus space for non-motorized vehicles and pedestrian.

On the contrary, Bridges of Bhairab, Atai and Atherobaki which are located in the eastern side of the Rupsa river is to have bypass function largely and are located in the periphery of Khulna urbanized area. The area where these bridges are planned to be located is suburban at present and will be urbanized in future according to Khulna Development Master Plan. Accordingly, Bridges of Bhairab, Atai and Atherobaki are also regarded as a city bridge, but it is in lesser degree.

10.1.3 Navigation Clearance at River Crossing Points

Navigation clearance beneath the Bridge is appropriately reserved to provide space vertically and horizontally for letting design vessel pass safely even on high water level. Navigation clearance of rivers in Bangladesh is controlled under jurisdiction of Bangladesh Inland Water Transport Authority (BIWTA).

There are four (4) possible bridges involved in the Study. Every bridge is named referring to river name at river crossing point, namely Rupsa Bridge in the western side of the Rupsa river and Bhairab Bridge/Atai Bridge/Atherobaki Bridge in the eastern side.

These four rivers have already had specified navigation clearances by the document which the BIWTA made to reply officially to the RHD's questionnaire. It is also pointed out that navigation clearance is not only dependent on maximum vessel in the past but also related to managerial policy of the river such as future development along the river and salvaging allowance.

Therefore, specified navigation clearances at each bridge crossing point are not planning parameters but precedent design criteria.

10.1.4 Appropriate Slope of Approach Section

Grade on approach road is closely relations to design speed and traffic capacity in terms of planning and scale of land acquisition area and social impacts in physical aspects. Greater grade may bring about lower cost in planning and smaller physical constraints, and on the contrary flatter is the slope, higher the planning cost and bigger the physical constraints.

Maximum grades of about 7 % without any critical length are deemed appropriate for a design speed of 65 km/h (40 mph in AASTHO). According to AASHTO, trucks display up to about 5% increase in speed on downgrades and about 7% or more decrease in speed on upgrades as compared to operation on the level, while all passenger cars can readily negotiate grades as steep as 5% without significant loss in speed below that normally maintained on level highway, except for compact cars with high weight/horsepower ratio.

However, 3% of maximum grade has been widely applied to bridges on National Highways in Bangladesh. Furthermore, salient features of road traffic in the study area are predominant non-motorized traffic, consisting of rickshaws and carts. These slow-moving vehicles transport passengers and cargoes considerably, and motorized vehicles manage to pass among such movements in urban area. Accordingly, the maximum grade of 2.4% is applied to Paksey Bridge in particular even the design speed of 100 km/h.

Under such circumstances, application of flatter grade is desirable yet practical from the aspect that trucks of quite an old vintage prevail and they also move slowly due to overloaded and shortage of horsepower among motorized vehicles.

10.1.5 Adverse Social Impacts

Adverse social impacts will be brought more or less by road development in urban area, even though route selection should be made to minimize violation of existing community and public facilities. One of most serious issues is resettlement of affected inhabitants due to land acquisition, and loss of arable land, fishery and public disturbances during construction also bring adverse impacts to society.

It is sure, however, that road is most fundamental infrastructure as a means of communication, and road development enables to improve society in terms of accessibility, mobility and quality of life as well as to increase land productivity along roads significantly.

"Slope of Approach Section" and "Adverse Social Impacts" are in trade-off relationship. Flatter grade makes slope of approach section longer, and embankment on long approach road results in larger land acquisition to increase probability of occurrence of social problems. It is sure that rail-cum-road bridge should require flatter grade in approach section and thus larger land should be acquired, taking into consideration difference of 3% in road from 1% in rail. For example, Rupsa Bridge which requires navigation clearance of 60 ft will have 700 m long approach road in case of 3%, and it will increase up to 2000 m long in case of 1%.

10.1.6 River Morphology

Technical feasibility is more important than others because an infrastructure such as bridge can create benefits only if facilities are sound.

Shifting of river bed, erosion of slope and embankment, scouring and sedimentation around structures in water are always taking place in the river. Such phenomena, called river morphology, are observed in all the rivers to greater or lesser degree in case of no river training.

To cope with the phenomena and to make the Bridge sound and stable, some river training is indispensable where building dike, ground sill and revetment of slope are built in general. Simultaneously, inspection roads are constructed normally on the top of embankment to maintain dike.

There are several evidences and certain witness to envisage scale of river morphology in the study area such as two times collapses of Rupsa East railway station in the past, 20 m advancing of ghat at Khulna terminal for two decades and so forth. The most remarkable phenomenon occurs in the Atai river where shifting of river bed of more than 500 m far is taking place in the vicinity of merging point with the Bhairab river. Accordingly, the bridge crossing the Atai river will require longer main span as well as large scale river training.

10.1.7 General Procedure of Bridge Planning

When a bridge is planned for a certain purpose, the bridge has to achieve the purpose under various kinds of constraints within a proper cost and time.

Under the existing conditions, several selections must be made before arriving at the final goal.

(1) Bridge Location

A bridge location has to be selected within an admissible range of proposed route in such a way that the bridge can exist and function for so long time as it is expected in the design.

Factors, which have to be taken into consideration from viewpoint of bridge engineering, are as below:

1) River Conditions

Such a portion of a river is preferable for a bridge location as is rather straight and simple without any sudden changes in the alignment, width and depth, and thus the riverbanks are stable. When the river alignment is complicated, then the current may be complicated as well, and then it will cause scouring at the foot of piers in the water and erosion of banks. Cost for river training may be much higher than construction cost of a bridge structure, if the river flow is too much rough.

Bridge location has to be selected in such a way that the bridge crosses in right angle in order to make the bridge shortest, to avoid the skewed bridge and to minimize the cost.

2) Land Conditions

Bridge construction requires lands not only for the right-of-way but also for temporary use as construction yards such as material stock and also access roads for transportation of materials and construction machinery. Thus bridge location must be selected, considering the availability of these land for a required period within appropriate distance.

If the area surrounding the bridge is too low, then huge amount of cost must be allocated to embank the land for permanent and temporary use above flood water level.

(2) Bridge Length

Total bridge length consists of a main bridge portion and a approach portion on both sides, and is determined by vertical alignment and the elevation that the bridge has to clear vertically. The vertical constraints to be cleared are generally navigation and high water level and/or ground traffic if any. For all the bridges under the study, the navigational constraint is dominant over the others.

The length of the main bridge is determined in relation with the river width, and the remaining parts on both sides of the river are approach lengths.

(3) Span length

Span length is one of the most important factors from the viewpoint of bridge engineering.

Generally the longer the span is, the higher the cost of superstructure is. But on the other hand, span length is usually limited by several conditions. Within these limitations and conditions, the most suitable span lengths are selected.

Regarding the bridges under the project, span lengths of the main bridge must cater the horizontal navigation clearance during and after construction and the head loss .

In the case of the project, the horizontal clearance dominates over the head loss, in determining the span length of the main bridge. The span length will be established by adding some allowance for construction stage to the horizontal navigation.

On the other hand, those in approach portions are frequently determined only for economical reasons.

(4) Bridge Type

There are several bridge types, such as a roadway bridge, railway bridge, pedestrian bridge, waterway bridge, road-cum-rail bridge and so on.

Depending on the bridge types, a bridge will have different intensity of loads and detail structure suitable to the bridge type.

(5) Configuration of Cross-section

The configuration of the cross-section must be carefully decided considering the volume and kinds of vehicles and other users by which the bridge can achieve the purpose.

(6) Structural types

A bridge consists of superstructures, substructures and foundations.

1) Superstructure

Each type of superstructure has its own proper range of span length.

Several types of superstructure may be considered that are suitable to span the length of a given gap, and these alternatives must be also compared each other from various viewpoints.

2) Substructure

Substructure consists of abutments and piers.

An abutment is usually constructed at both ends of the bridge, and it works as a support for the superstructure and transfers the forces to the foundation and also as a retaining wall. There are a gravity type, semi-gravity type, inverted T type and buttressed type depending on the structural height.

While a pier is constructed in-between the both abutments, and supports the superstructure. There are a pile bent type, wall type, inverted T type and a rigid frame type.

Construction procedures are also important factors in deciding a type of substructures especially when the substructures are to be constructed offshore.

3) Foundation

A foundation is a part of the bridge structure that transfers the forces coming through the substructure above to the ground.

Driving piles and cast-in-situ piles of concrete or steel, and also concrete caisson are usually adopted for foundations of a modern bridge.

Selection of the foundation type depends on the depth of ground conditions, structural features and construction conditions.

(7) Bridge materials

Selection of major structural materials is also an essential and important part of the bridge planning, as it will affect not only the construction period and method but also the total cost including the initial and maintenance cost.

Materials for modern bridge construction are usually concrete (either reinforced or prestressed) or structural steel.

10.2 Design Criteria

The following design criteria are proposed for the Study. These are neither complete nor comprehensive but minimum requirements to conduct preliminary design, construction plan and cost estimates.

10.2.1 Design Criteria for Highway

(1) Geometric Design Standard

A geometric design standard for road projects financed by foreign assistance is usually referred to foreign standard in Bangladesh. A Policy on Geometric Design of Highways and Streets of the American Association of State Highway and Transportation Officials (AASHTO) has been widely used as a geometric design standard. The geometric design standard of Japanese Standard and AASHTO will be referred if established design standards or design criteria customarily applied in Bangladesh are not sufficient. Table 10.2.1 shows the adopted design standards and comparison of major design elements.

Table 10.2.1 Salient Feature of Other Project

Project Name	Design Standard	Classification	Design Speed (km/h)	Max. Grade (%)	Remarks
Jamuna Bridge Access Roads	AASHTO	National Highway	65-100	4-6	
Jamuna Bridge	BS	National Highway	100	2 (0.5)	
5-Bridges	AASHTO, Japanese Standard	National Highway	100	Level	
Paksey Bridge	AASHTO	National Highway	100	3 (2.4)	
Second buriganga Bridge	AASHTO	National Highway	65	2 (2)	Located in urban area and open to rickshaw
Meghna-Gumuti Bridge	AASHTO	National Highway Category A	80	3 (3)	
Meghna Bridge	AASHTO	National Highway Category A	80	3 (3)	

Notes : Figures in parenthesis show actually adopted value.

(2) Design Speed

Design speed is the maximum safe speed that can be maintained over a specified section of road when conditions are so favorable that design features of road govern. The design speed is to be determined logically with respect to the terrain, adjacent land use, type of road and the design speed of adjoining section.

In urban area, design speed for arterial roads ranges from 60km/h to 100km/h by the AASHTO, and from 40km/h to 60km/h by the Japanese Road Standard.

Khulna Bypass is designated as an urban arterial road and becomes the part of Khulna road network in future.

Although travel speed is the dominant consideration for regional arterial road, urban arterial roads should be capable of carrying high traffic volumes. Moreover, sometimes it is necessary to compromise on physical constraints and economic limitations to fit certain elements of design within availability of right-of-way.

The followings may warrant the design speed of 60 km/h applied to the through traveled lanes for the Bridge:

* to avert excessive eviction of local inhabitant by applying sharper curves;
* to make it practical to apply the lane width of 3.50 m, which is recommended in this sub-section;
* to accommodate the entire scheme of Khulna Bypass with reasonable construction economy yet level of service; and
* to install a toll plaza of barrier-gate type on the through traveled lanes where all vehicles stop for paying toll just in case of toll bridge.

(3) Design Vehicles

The physical characteristics of vehicles and proportions of variously sized vehicles using urban roads are positive controls in geometric design. For purpose of geometric design, each design vehicle has larger physical dimensions and larger minimum turning radius than those of almost all vehicles in its class.

Three general classes of vehicles have been selected, namely passenger car, truck and semi-trailer. The passenger car class includes sedan, wagon, van and pick-up, while the truck class includes bus, single-unit truck and so forth. The semi-trailer class represents truck tractor/semi-trailer combination.

Design vehicle in Asian Highway criteria is 20ft Semi-trailer, which is considered for international container transportation and in view of promotion of trade between regional and interurban centers. However, since 40ft semi-trailer is presently used in Bangladesh and it will become major constituent in containerization, 40ft semi-trailer is deemed appropriate the design vehicle for the Bridge.

Table 10.2.2 gives dimensions of design vehicles of the AASHTO.

Table 10.2.2 Dimensions of Design Vehicles of the AASHTO

	Dimension (ft)		
Design Vehicle Type	Height	Width	Length
Intermediate Semi-trailer	13.5	8.5	50
Single Unit Bus	13.5	8.5	40
Single Unit Truck	13.5	8.5	30
Passenger Car	4.25	7	19

(4) Vertical Clearance

4.9 meters high vertical clearance should be kept for overhead obstacles, including 16 centimeters allowance for possible future resurfacing.

(5) Lane Width

3.0 m to 3.75 m lane widths are generally used, with 3.5 m lane predominant on most type of highways. 3.75 m lane width is internationally accepted as the widest possible lane width since the lane wider than 3.75 m is hard to regulate traffic flow. In case of the design speed of more than 60 km/h applied to highway, 3.50 m wide lane width is desirable on both rural and urban facilities.

The lane width of 3.50 m is assumed to the study. Just in case that the lane width of 3.75 m should be applied, the construction cost of Rupsa Bridge would increase up to 7%.

(6) Embankment Height

Minimum embankment height seems to be 4.66 meters high in the study area where High Water Level is found to be 3.41 meters, which is highest water level recorded on the past 41 years (1955• `1996), including 1.25 meters allowance for pavement structure. Because durable years of pavement become short period, if pavement is flooded with water.

(7) Navigation clearance

The Bangladesh Inland Water Transport (BIWTA) has postulated the following navigational clearance requirements.

Clearance	Rupsa	Athrabaki	Atai	Bhairab
Class	I	III	II	II
Horizontal	250ft (76.22m)	100ft (30.48m)	250ft (76.22m)	250ft (76.22m)
Vertical	60ft (18.30m)	25ft (7.62m)	40ft (12.20m)	40ft (12.20m)

The vertical clearance shall be kept above the Standard High Water Level.

The horizontal and vertical clearance shall be kept not only after the completion but also during the construction period.

Consequently span length (spacing of center-to-center of piers) will be determined considering width of the pier, dimension of the temporary cofferdam for constructing substructure and also some allowance in addition to the horizontal navigation clearance.

10.2.2 Design Criteria for Bridge

(1) Live loads

1) Roadway Live Load

It is desirable to use a roadway live loading which reasonably and accurately represents anticipated future loading, although selection of an appropriate loading presents some difficulties for the Rupsa Bridge, where development of road traffic is clearly at an early stage.

Most developed countries have their own national loading specification such as AASHTO (USA), BS 5400 (UK) and Specifications for Highway Bridge of Japan Road Association, which have gained a wide international acceptance and thus may be adopted for the Rupsa Bridge as it is or modified.

On the other hand, it is desirable to adopt a common live loading system throughout the country or at least along a same highway route.

HS20-44 (AASHTO) live load has been frequently adopted for the structural design of bridges in Bangladesh. Meghna Bridge, Meghna Gumuti Bridge, 5 Bridges on Dhaka-Chittagong Highway and the Second Buriganga Bridge are designed by HS20-44.

Recent rationalization of international container transport requires the movement of heavier and larger trailers, and this requires road and bridge design to meet these traffic requirements.

As the Rupsa Bridge will connect the Mongla Port with Khulna and the hinterland, and thus heavier vehicles may be expected, 25% over load of HS20-44 is the appropriate load, which is same as that of Paksey Bridge located closely to the Rupsa Bridge.

2) Railway live load

The axle load shall be 22.5 tons.

(2) Dead load

The dead load shall consist of the weight of the entire structure, including the roadway, side walks and public utility services.

(3) Wind load

Wind load shall consist of moving uniformly distributed loads applied to the exposed area of the structure.

The load intensity will be calculated based on the data recorded at Khulna Observatory of the Bangladesh Meteorological Department, including the maximum wind velocity of 160 km/h (44 m/sec) recorded during the cyclone of 1988.

(4) Seismic effects

Two kinds of seismic zoning maps and also seismic factors are available in Bangladesh.

0.05, which is higher, is taken as the seismic factor for the study.

(5) Thermal effects

Range of temperature change is determined according to the past record, and the bridge is so designed as to allow the thermal expansion and shrinkage.

Coefficient of thermal expansion shall be taken as 10×10^{-6}°C for concrete.

(6) Boat collision

Collision force by boat is applied to a certain height of the bridge for the design purpose.

Collision force of 5,000 kN was adopted for both Jamuna and Paksey Bridge, and so similar value of the force is considered.

(7) Supporting Strata

Based on the boring test at the sites of Bhairab, Atai and Atharabaki conducted by the Study Team and Rupsa by ADB, the supporting strata are situated at depths of 40 though 50m.

(8) Current velocity

Current velocity is necessary for the purpose of construction planning of substructure, and design of pier itself and also scouring around the footing.

No other data except those measured during the study by the study team, is available and longer survey period may be required to satisfy the needs.

(9) Water level

Water level is essential as a factor of design criteria, that governs height of revetment, embankment, construction planning and also vertical clearance.

The maximum value of water level in elevation at Khulna is 3.22 m (PWD), the minimum is ñ0.73 m (PWD). The difference is almost 4m according to the data observed by Bangladesh Water Development Board at 241 Station Khulna.

The Standard Water Level (SWL) at the site was given by BIWTA as +3.00m (PWD).

(10) Salinity

The salinity of the Rupsa River water is more than 20,000 micro-mhos, which is similar to that of seawater, and seems to rise year by year.

Under such circumstances, steel materials will easily corrode and periodical inspection and maintenance are required.

(11) Summary of Deign Criteria

The design criteria are summarized in Table 10.2.3.

Table 10.2.3 Summary of Design Criteria for Bridge

1	Navigation Clearance		Rupsa	Bhairab	Atai	Atherobaki
		Class	I	II	II	III
		Horizontal	76.22	76.22	76.22	30.48
		Vertical	18.3	12.2	12.2	7.62
2	Live Load	Railway	22.5 ton			
		Roadway	ASSHTO (HS20-44 plus 25%)			
3	Wind Load		44 m/sec			
4	Seismic Effect		0.05			
5	Thermal expansion		10x10^{-6}/°C			
6	Boat collision		5,000 kN			