3.2 Traffic Demand Forecast

3.2.1 Procedure

The results of the Phase 1 study indicated the necessity for more specific traffic demand forecast in the Phase 2 study by establishing more detailed conditions for traffic flow simulation at surrounding area of the planned Khulna Bypass including Rupsa Bridge.

The total procedure for traffic demand forecast through the Phase 1 and Phase 2 is shown in Fig. 3.2.1. The outlines of main items at each step are described as follows:

(Phase 1)

(a) Zoning

Zones were established for traffic forecasting based on the smallest administrative areas for which socioeconomic indicators were available as well as the accuracy of OD survey from the manner of survey implementation and the survey locations carried out in this Study.

Zoning is done with Khulna and Mongla areas as the center of study areas. Khulna area was split into four zones, and Khulna and Bagerhat zilas was divided upon the thana boundaries, whereas other districts were combined into zilas appropriate to the direction of the future trunk road. The number of zones established thus was finally 27.

(b) Making Present Origin and Destination (OD) Tables

The present OD tables by vehicle type were constructed based on the data from traffic survey (traffic count survey and roadside interview survey) in the Phase 1. The accuracy of OD tables has been checked in terms of implementation of traffic flow simulation on the present road network.

(c) Future Total Traffic Demand (Control Total)

In general, traffic demand increases in accordance with GDP and population growth, domestic and international trade as well as expansion of agriculture and industrial production. Actually, traffic demand (passengers, freight) in Bangladesh is basically increasing until now, and it is a growth rate in passenger and freight transport exceeding the rate of GDP growth.

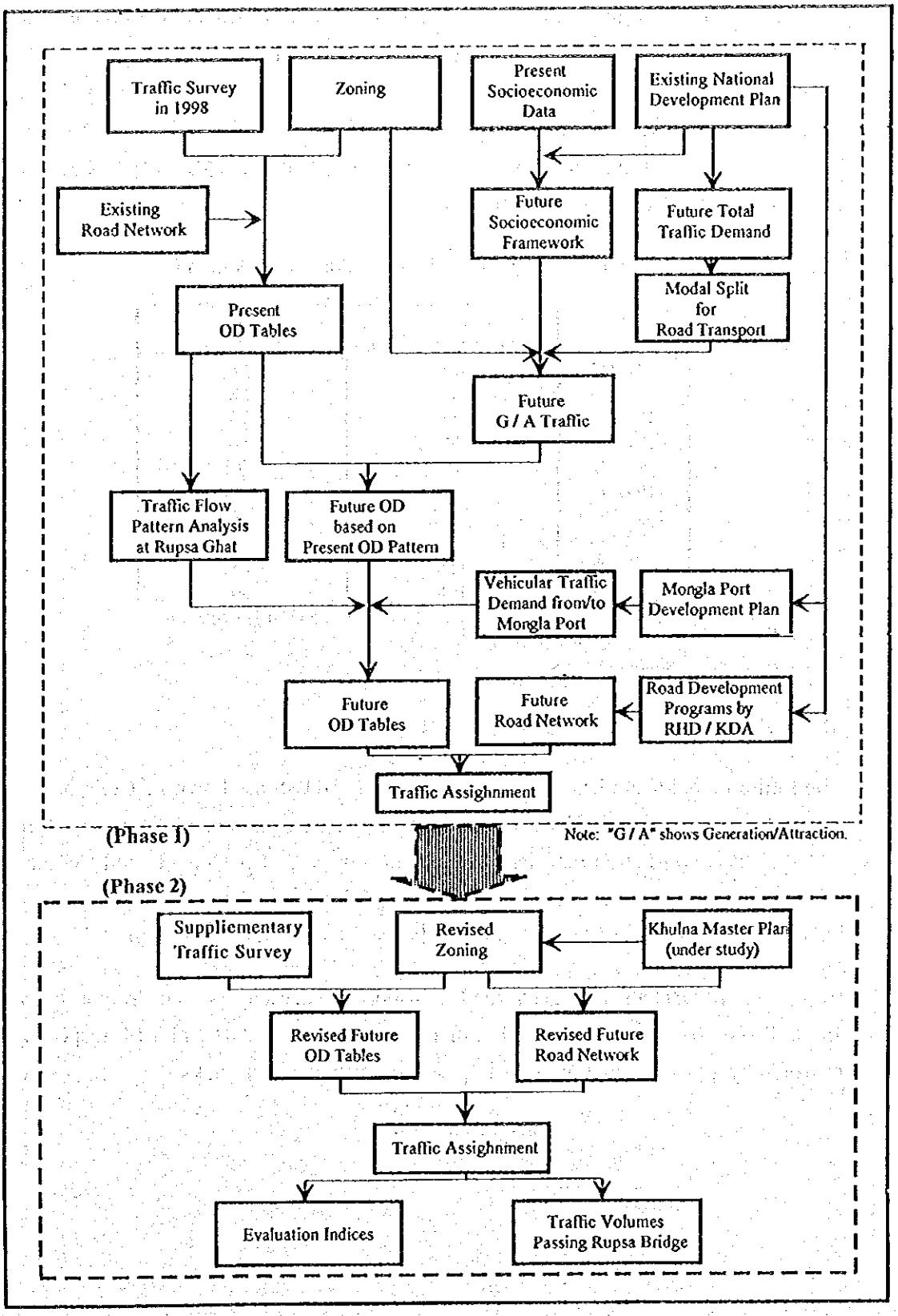


Fig. 3.2.1 Process of Traffic Demand Forecast

The study in Phase 1 applied the forecast results for total traffic demand (control total) derived within the national transport plan formulated by "Bangladesh Integrated Transport System Study (hereinafter referred to as "BITSS")" issued by Planning Commission in June 1998 as priority planning Figs. (see Table 3.2.1). Accordingly, this study applied future increases between 1997/98 and 2014/15 of 2.54 times for passenger demand, and 2.75 for freight demand.

Table 3.2.1 Future National Transport Demand

Year	Passenger (billion passenger-Km)	Freight (billion ton-Km)
1974/75	17	2.6
1984/85	35	4.8
1988/89	57	6.3
1992/93	66	9.0
1996/97	72	10.2
1997/98	77	10.9
1999/2000	89	13
2004/2005	116	17
2009/2010	150	23
2014/2015	196	30

Note : 1) Values for passenger-Km and ton-Km in 1997/98 are estimated by the Study Team.
Source : BITSS

(d) Modal share analysis for different transport modes

The future modal share has been forecasted in the BITSS as shown in Table 3.2.2 and Fig. 3.2.2. The study in Phase 1 applied the share for road transport forecasted in the BITSS. It is considered that increase in road transport of passengers and freight will be guaranteed by the shared use of the Jamuna Multipurpose Bridge, the construction of Dhaka Eastern Bypass and road bridges at Paksey, Khulna and Ashuganji.

Based on the BITSS forecasts, road transport of passengers and freight between 1997/98 and 2014/15 was expected to increase by factors of 2.81 and 3.14, respectively, mirrored by a proportional increase in passenger vehicles and trucks.

Table 3.2.2 Estimates of Modal Shares

Year	Passenger					Freight				
		Modal Distribution					Modal Distribution			
	Passenger-Km (billion)	Road (%)	Rail (%)	Water (%)	Total (%)	Ton-Km (billion)	Road (%)	Rail (%)	Water (%)	Total (%)
1974/75	17	54	30	16	100	2.6	35	28	37	100
1984/85	35	65	20	16	100	4.8	48	17	35	100
1988/89	57	68	17	15	100	6.3	59	11	30	100
1992/93	66	75	12	13	100	9.0	61	7	32	100
1996/97	72	73	13	14	100	10.2	63	7	30	100
1997/98	77(1.00)	-	-	-	100	11(1.00)	-	-	-	100
1999/2000	89(1.15)	76	10	13	100	13(1.19)	65	10	25	100
2004/2005	116(1.50)	79	10	11	100	17(1.56)	68	11	21	100
2009/2010	150(1.94)	80	10	10	100	23(2.11)	70	11	19	100
2014/2015	196(2.54)	82	10	8	100	30(2.75)	72	11	17	100

Note: 1) Data relate to Mechanized transport only and data relating to road transport referes to Bus, Truck, Car and other four wheelers.
2) Values for passenger-Km and ton-Km 1997/98 are estimated by the Study Team.

Souce: BITSS

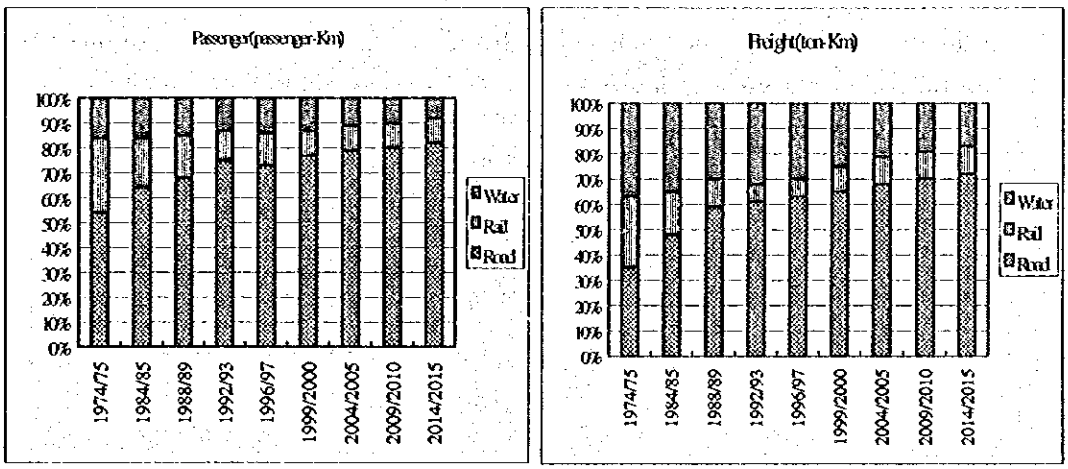


Fig. 3.2.2 Estimates of Modal Shares

(e) Future traffic volume by zone

Forecasting of future traffic volumes in the various zones was carried out using the control total as well as socioeconomic indicators by zone. Indicators used in this study included zonal population indicators for forecasting passenger traffic volumes by zone, and freight traffic demand done by BITSS on the zila level.

(f) Traffic patterns analysis at the Rupsa Ferry ghat

Latent demand for the Rupsa Ferry is presently indicated by much shuttle service to the Rupsa Ferry ghat. It is predicted that traffic flow pattern will greatly change in the future with the construction of a bridge nearby. The latent traffic demand for Rupsa

River crossing that will arise upon the construction of the bridge can be forecasted on the basis of Origin-Destination studies of the existing situation. The estimated results are shown in Table 3.2.3.

Table 3.2.3 Latent Traffic Demand for Rupsa River Crossing

(trips/day)

	Khulna from Rupsa		Rupsa from Khulna	
	1998	2015	1998	2015
Autorickshaw	455	1,373	352	1,062
Bus	296	847	260	745

Source: Study Team

(g) Vehicular Traffic Volumes Arising from Mongla Port Freight Handling

About two (2) million ton cargo (including Nepalese cargo) handled at the jetty of Mongla Port, separately forecasted in Phase 1, was applied in the forecasting of vehicular traffic volumes generating from the harbor freight handling. Vehicular traffic volumes were as follows:

	(1998)	(2015)	
Trucks	120	140	(trips/day)
20-foot Trailers	0	600	
40-foot Trailers	0	360	
Passenger Vehicles	60	550	
Total	180	1,650	

Moreover, the vehicular traffic volumes in the case of the railway extension from Khulna to Mongla Port were examined in Phase 1. In the case, it was forecasted that a part of long-distance freight transport demand (for example, freight transport demand to Nepal) would be mainly diverted to rail transport.

(h) Future OD Table Forecasting

Based on the above-mentioned information, future OD tables were estimated in accordance with the following procedure:

(i) Future OD projections were in principal done by the application of Present Pattern Method.

(ii) OD traffic volume estimates prepared by the Present Pattern Method were adjusted by applying future traffic flow patterns forecasted for the Rupsa Ferry ghat area.

(iii) Further, OD traffics generating from the handling of freight at Mongla Port were added to the above OD.

(i) Establishment of future road network

The future road network was consisted of the national highways, feeder roads including urban roads and the roads which future construction was certain. Two alternative routes for the Khulna Bypass, route A and B, as well as its access links were added to the network.

(j) Traffic assignment

The future OD traffic volumes were assigned upon the future road network.

(Phase 2)

The future OD tables are subdivided by more detailed traffic zones in the study area, and the future traffic is assigned on more detailed road network than that of Phase 1 to examine necessary improvement of connecting roads.

(k) Revised zoning

According to the above-mentioned purpose, the zoning in the Phase 1 is looked again based on the information for land use and road network plan in the KDA Master Plan Study area (under study), taking the results of supplementary traffic survey into consideration.

(l) Revised future OD tables

The future OD tables forecasted in the Phase 1 are subdivided in accordance with the revised zoning. At that time, ratios for zone subdivision are calculated by the area population estimated in the KDA Master Plan Study.

(m) Revised future road network

Future road network is revised based on the proposed road network in the KDA Master Plan Study, especially access roads to Khulna Bypass.

(n) Traffic assignment

Revised future OD traffic volumes are assigned upon the revised future road network.

(o) Evaluation indices, Traffic volumes passing Rupsa Bridge

Evaluation indices and traffic volumes using Rupsa Bridge are calculated based on the results of traffic assignment.

3.2.2 Revised Future OD Tables

(1) Revised Zoning

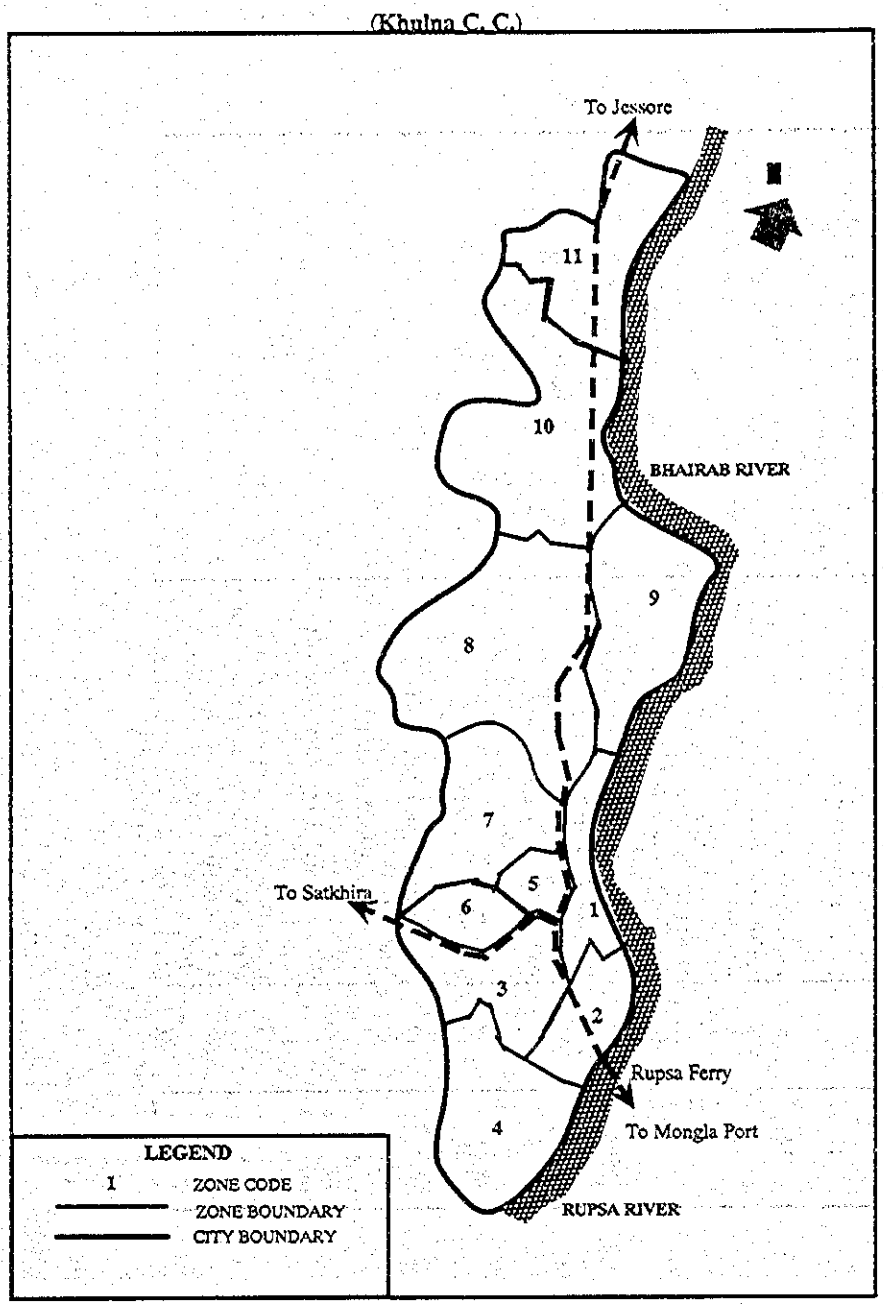
In principle, the zoning in Phase 2 maintained the traffic zone boundary established in Phase 1, and the relative zones that are mainly included in Khulna city are subdivided. The subdivisions are revised based on the information on land use, area population and road network plan in the KDA Master Plan Study area.

The traffic zones established in this Study are shown in Table 3.2.4 and Fig. 3.2.3. As a result, four traffic zones in Khulna city were subdivided into 11 traffic zones in the Phase 2. Additionally, traffic zone No. 14 in the Phase 1 is divided into east (Zone 21) and west (Zone 22) sides by the Rupsa River, taking condition of access link to the Khulna Bypass into consideration.

Table 3.2.4 Revised Zone Code

Zone No. in Phase 2	Zone No. in Phase 1	Areas	Zone Characteristics
1	1	Khulna C.C.-1(W21,W23)	City center (CBD), including Khulna Station & BIWTA Ghat. High population density
2		Khulna C.C.-1(W22,W29,W30)	Commercial & housing area, including Rupsa Ghat. High population density
3		Khulna C.C.-1(W24,W27,W28)	Commercial & housing area, including planned housing area (Nirala). Very high population density
4		Khulna C.C.-1(W31)	Industrial & housing area, including shipyard. High population density
5	2	Khulna C.C.-2(W19,W20)	Commercial & housing area, including KDA Office. Very high population density
6		Khulna C.C.-2(W25,W26)	Housing area. Medium population density
7		Khulna C.C.-2(W17,W18)	Housing area, including bus terminal, new market, administrative & health facilities. Medium population density
8	3	Khulna C.C.-3(W9,W14,W16)	Housing area, including Khulna divisional stadium, public & planned housing area (Mujgunni). Medium population density
9		Khulna C.C.-3(W7,W8,W10-W13,W15)	Industrial & housing area, including public & planned housing area (Khalishpur). Very high population density
10	4	Khulna C.C.-4(W3-W6)	Housing & warehouse area, including Daulatpur town center & agriculture trainning institutes. High & medium population density
11		Khulna C.C.-4(W1,W2)	Industrial, warehouse & housing area. Medium & low population density
12	5	Rupsa thana	-
13	6	Fakirhat thana	-
14	7	Rampal thana	-
15	8	Mongla-port thana	-
16	9	Mollahat thana	-
17	10	Bagerhat, Chitalmari and Kacha thana	-
18	11	Morrelganj and Sarankhola thana	-
19	12	Khan Jahan Ali & Phultara thana	-
20	13	Digalia and Terokhada thana	-
21	14	Batiaghata(East)	-
22		Batiaghata(west) & Dacope thana	-
23	15	Dumria thana	-
24	16	Paikgachha and Koyra thana	-
25	17	Satkhira zila	-
26	18	Jessore zila	-
27	19	Magura, Rajbari and Faridpur zila	-
28	20	Narail zila	-
29	21	Jhenaidah, Kushita, Meherpur, Chuadanga zila	-
		and Rajshahi Division	-
30	22	Gopalganj, Madaripur and Shariatpur zila	-
31	23	Barisal Division	-
32	24	Dhaka Division(excluding soutern area	-
		of Padma River), Chittagong & Sylhet Division	-
33	25	West Bengal (India)	-
34	26	Tripura, Assam and Meghalaya (India)	-
35	27	Nepal and Bhutan	-

Note: "W1" represents Ward No. in Khulna C.C.



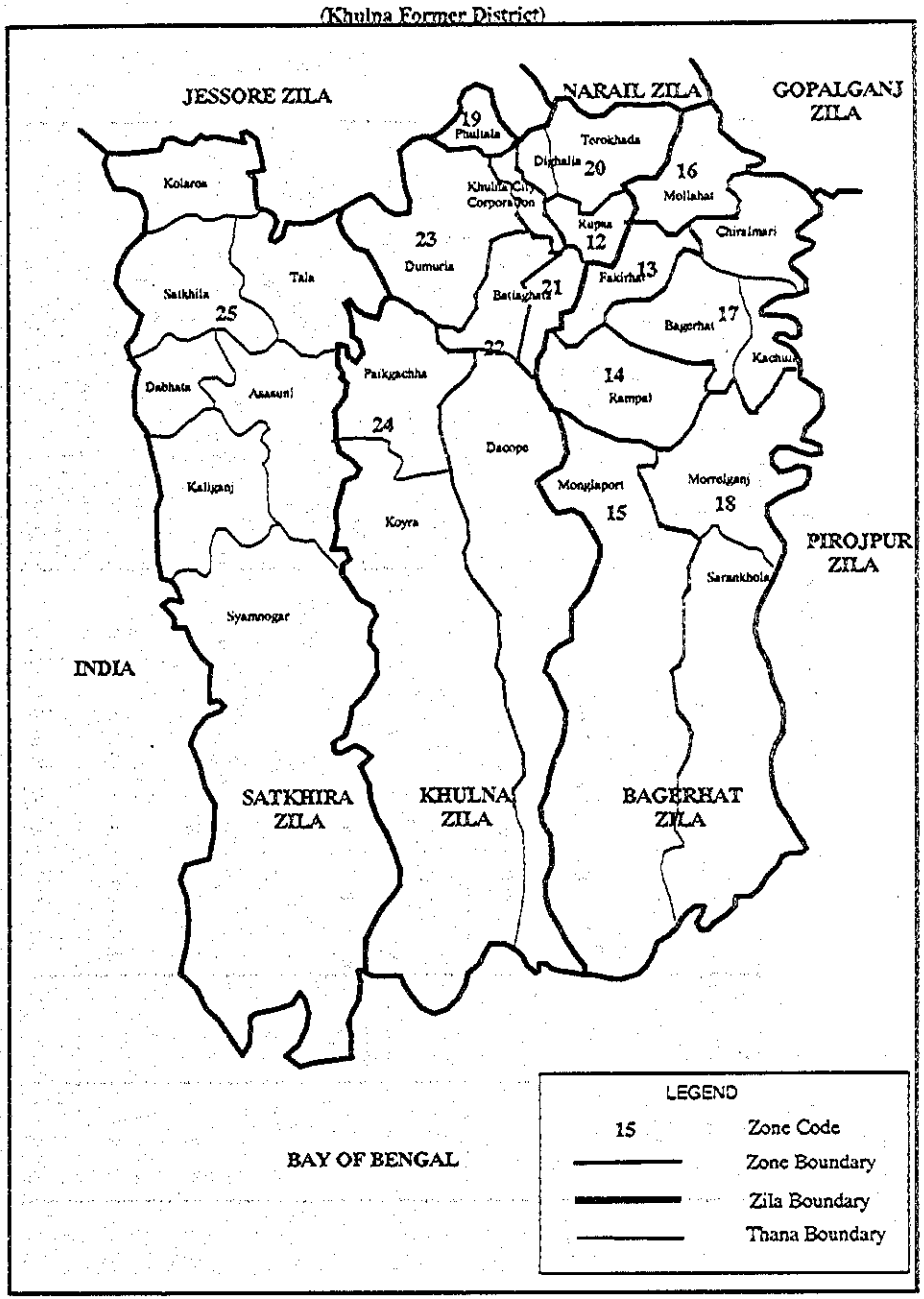


Fig. 3.2.3 Revised Zone Map

(2) Future OD Tables

The future OD tables forecasted in the Phase 1 are subdivided in accordance with the revised traffic zoning. At that time, the ratios of zone subdivision are calculated by using the area population estimated in the KDA Master Plan Study. Table 3.2.5 shows the ratios for traffic zone division. Then revised future OD table is made based on the new traffic zoning. Fig. 3.2.4 shows desire line constructed in accordance with the future OD table.

Table 3.2.5 Ratio for Traffic Zone Division

Zone No. in Phase 2	Zone No. in Phase 1	Division Ratio	Ward No. in Khulna C.C.
1	1	0.207	W21, W23
2		0.310	W22, W29, W30
3		0.354	W24, W27, W28
4		0.129	W31
Total		1.000	(Khulna Sadar area)
5	2	0.302	W19, W20
6		0.259	W25, W26
7		0.439	W17, W18
Total		1.000	(Sonadanga area)
8	3	0.348	W9, W14, W16
9		0.652	W7, W8, W10, W11, W12, W13, W15
Total		1.000	(Khalishpur area)
10	4	0.566	W3, W4, W5, W6
11		0.434	W1, W2
Total		1.000	(Daulatpur area)
21	14	0.158	East-side
22		0.842	West-side
Total		1.000	(Batiaghata & Dacope thana)

3.2.3 Traffic Assignment

As in Phase 1, the calculation for simulation of traffic assignment is carried out by using the software "STRADA (System for Traffic Demand Analysis)", supplied by JICA.

(1) Future Road Network

Future road network established for traffic assignment in Phase 1 is basically maintained, and it in Phase 2 is mainly revised with the focus on road network in the KDA Master Plan Study area, especially access links to Khulna Bypass route (Route A) selected in Phase 1.

The future road network made in this study is shown in Fig. 3.2.5.

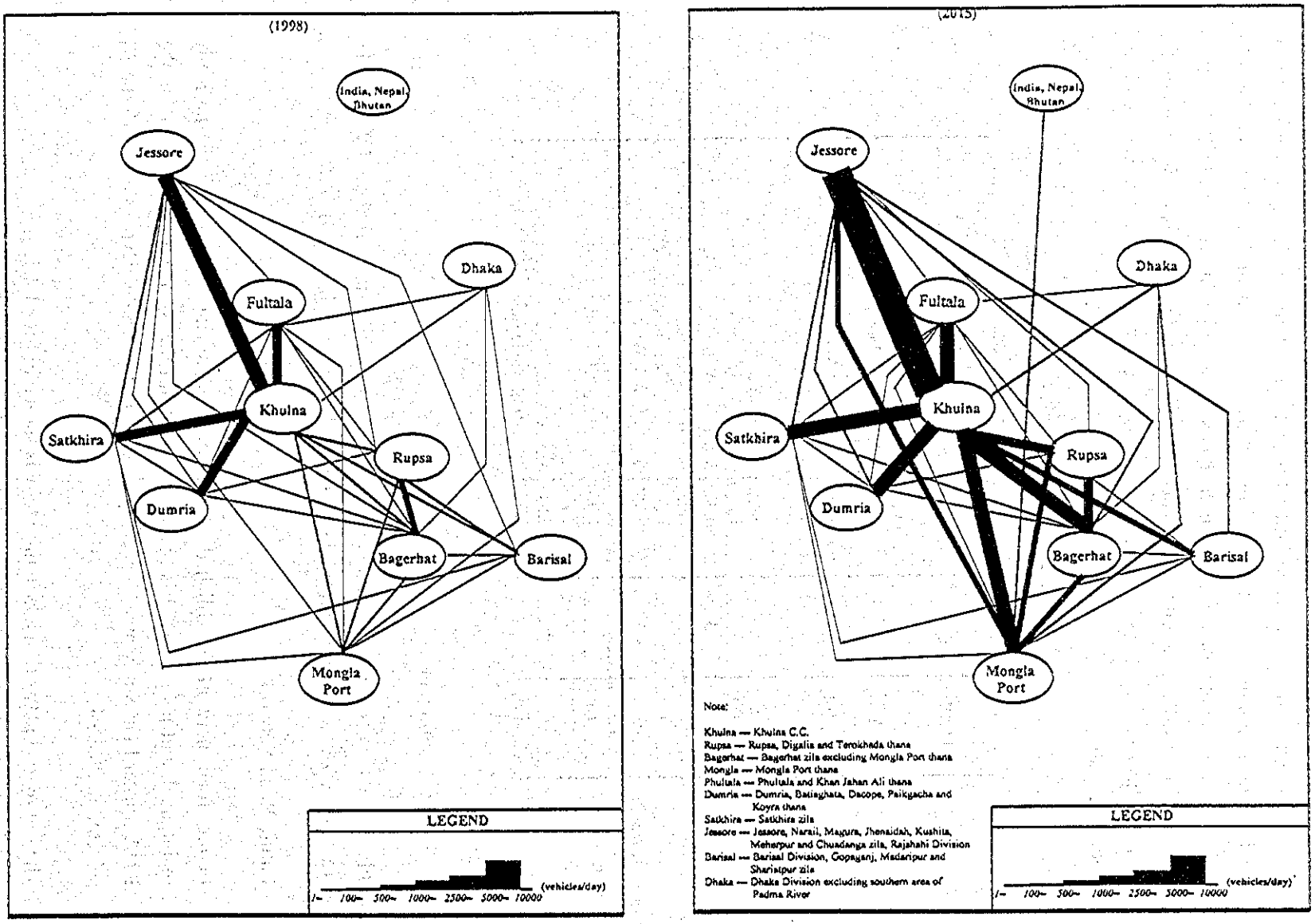


Fig. 3.2.4 Desire Line in 1998 and 2015

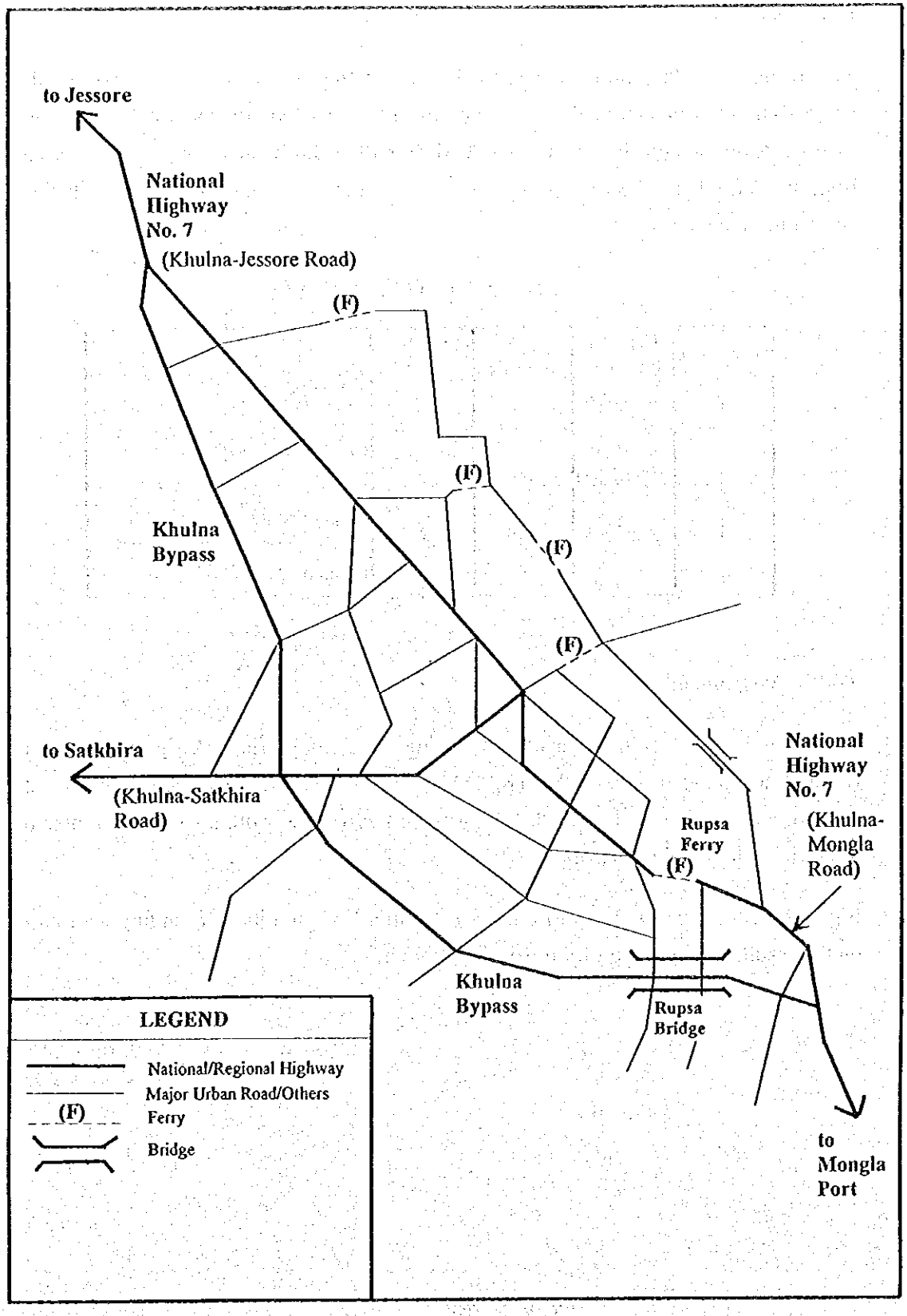


Fig. 3.2.5 Revised Future Road Network

(2) Link Specifications

The distance and lane number for each link consisting of road network is specified by using RHD road inventory data, and data from the road improvement program as well as road development plan for the KDA Master Plan Study area. Moreover, for each link, the traffic variables of capacity (Q) and speed (V) are arranged in a Q - V table, as shown in Table 3.2.6.

Table 3.2.6 Q- V Pattern

Q - V Code	Capacity (pcu/day)	Max. Velocity	No. of Lanes	Remarks
1	22,200	60	2	Low class of National Hiways & high class of Regional Highways as intercity roads
2	16,400	60	2	Low class of Regional Highways as intercity roads
3	12,900	60	2	Other intercity roads
4	7,800	40	2	Urban roads

(3) Traffic Assignment

Traffic assignment is implemented by using the "Equilibrium Assignment Method (EAM)" available in the JICA STRADA program. The EAM is based on the total system optimization, and loads the OD trips to the road network so as to minimize the total travel time in the network.

Fig. 3.2.6 shows the future traffic flow in Khulna C.C. and its surrounding area based on the results of simulation for traffic assignment.

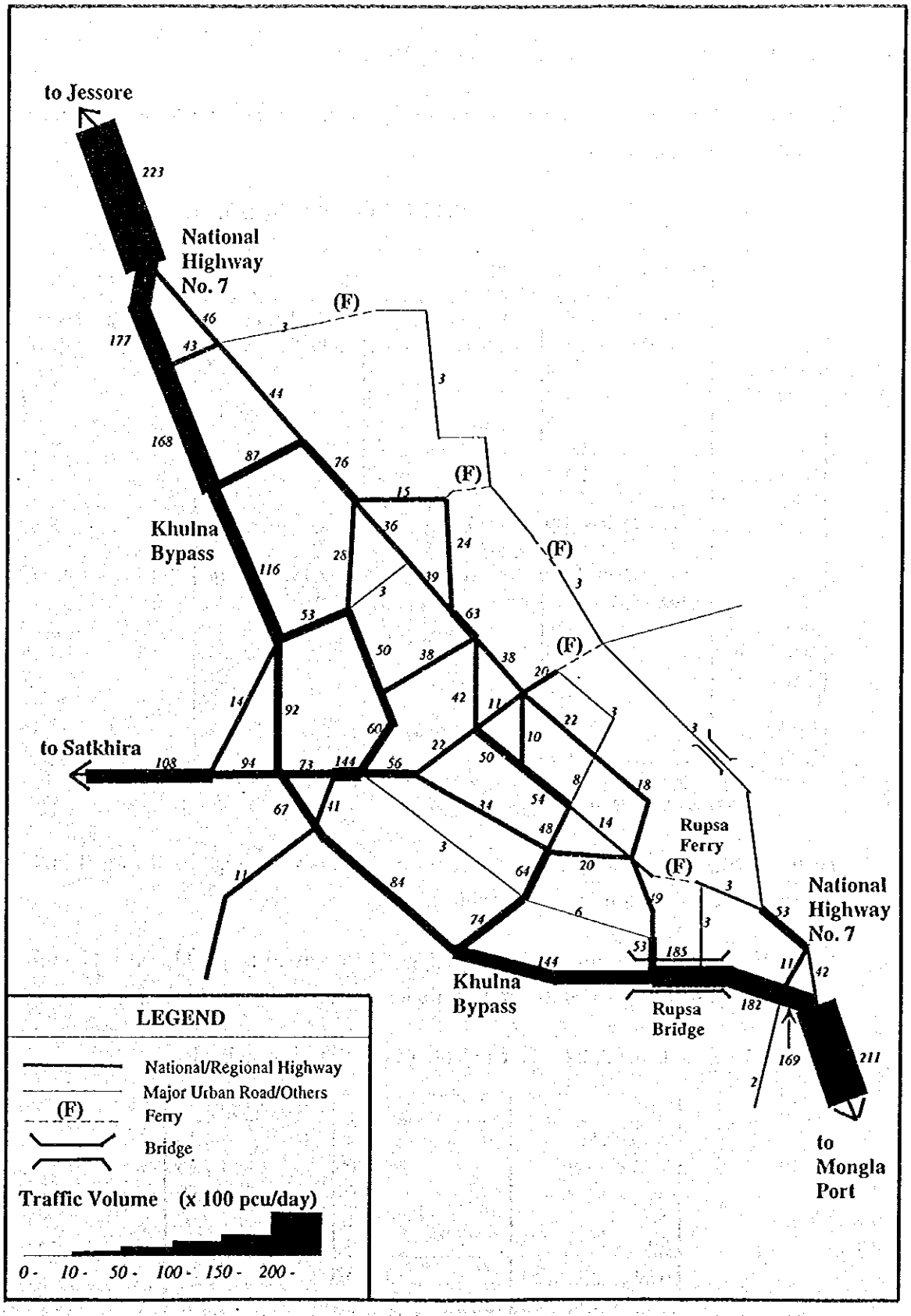


Fig. 3.2.6 Future Traffic Flow

(4) Evaluation Indices, Traffic Volumes Passing Rupsa Bridge

Table 3.2.7 shows evaluation indices (e.g. total vehicle-km and vehicle-hour) calculated from the assignment results.

Table 3.2.7 Total Vehicle-km and Vehicle-hour

Total pcu-km & pcu-hour				
	(a) Without Project		(b) With Project	
	Total pcu-km (x 1000 pcu-km/day)	Total pcu-hour (x 1000 pcu-hour/day)	Total pcu-km (x 1000 pcu-km/day)	Total pcu-hour (x 1000 pcu-hour/day)
Motorcycle	84	4	73	2
Autorickshaw	414	23	349	9
Car	308	12	272	7
Bus	1,421	75	1,199	29
Truck	1,512	60	1,304	32
Total	3,739	174	3,197	79
Total vehicle-km & vehicle-hour				
	(a) Without Project		(b) With Project	
	Total vehicle-km (x 1000 vehicle-km/day)	Total vehicle-hour (x 1000 vehicle-hour/day)	Total vehicle-km (x 1000 vehicle-km/day)	Total vehicle-hour (x 1000 vehicle-hour/day)
Motorcycle	280	13	243	7
Autorickshaw	414	23	349	9
Car	308	12	272	7
Bus	568	30	480	12
Truck	756	30	652	16
Total	2,326	108	1,996	51

Note: "With Project" and "Without Project" represent the cases with and without the southern section of Khulna Bypass, respectively.

Then, based on the assignment results, traffic volumes passing the Rupsa Bridge is analyzed, and its result is shown in Table 3.2.8.

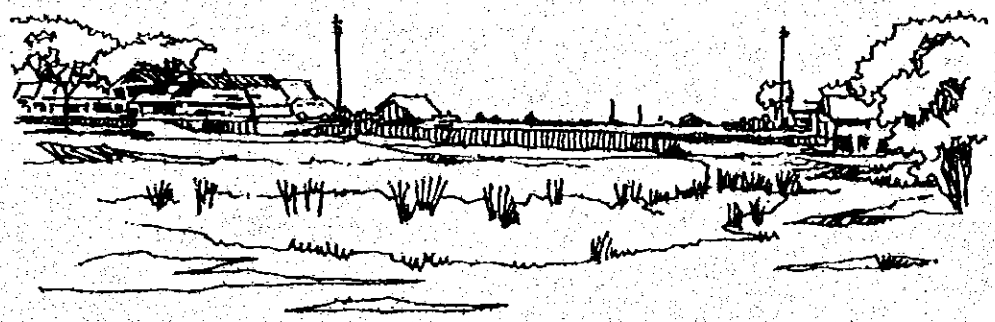
The traffic demand passing the Rupsa Bridge is forecasted about 11,100 vehicles/day (about 18,500 pcus/day), and its average trip length is 53.8 km.

Table 3.2.8 Traffic Volumes Passing Rupsa Bridge

	pcu/day	vehicle/day
Motorcycle	349	1,163
Autorickshaw	2,466	2,466
Car	1,097	1,097
Bus	9,016	3,606
Truck	5,524	2,762
Total	18,452	11,094
Average Trip	53.8 Km	

CHAPTER 4

PHYSICAL CONDITIONS OF THE STUDY AREA AND ENGINEERING SITE SURVEY



CHAPTER 4 PHYSICAL CONDITIONS OF THE STUDY AREA AND ENGINEERING SITE SURVEY

4.1 Topographic Conditions of the Study Area

4.1.1 Maps and Aerial Photos

The maps and aerial photos collected through Phase 1 and 2 Studies are as follows:

(1) Topographic Maps

1) Revised KDA Landuse and Topographic Survey Map (KDA Master Plan Area)

2) 1997-98 by KDA Scale 1 inch = 66 feet (1:792)

2) Land Use Map of Khulna City (KDA Master Plan Area)
May, 1988 by KDA Scale 1:10,000 11 sheets

3) Khulna Master Plan Map
Scale 1 inch = 330 ft. (1:3,960 by KDA)
In 1968 - 1970, 6 sheets among total 32 sheets
(Note: Khulna Master Plan was revised in 1998.)

4) Base Map: Rupsa, Digharia and Terakhada Thanas
1993 by Local Government Engineering Department, Scale 1:50,000

5) 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

6) Map of the Khulna City Corporation Area
Scale 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

4.1.2 Topographic Survey

Topographic Survey is being conducted along three (3) alternative routes. The terrain of survey site is flat with less than 5m elevations, and the agricultural landuse is widely spread except residential and industrial areas along the Rupsa river.

The survey comprised the following works.

- Centerline Survey
- Profile Survey
- Cross Section Survey
- Electronic Plane Survey
- Mapping
- Reporting

4.1.3 The Location and Description of Global Position System (GPS) used for Topographic Survey

There are no established controlling point of coordinates in Khulna and its surroundings although primary control points established in East Pakistan regime are found totally damaged.

A concrete marker, referred as Reference Bench Mark No. 1 is established by the study team on the western dike of the Rupsa, which has the following GPS information.

Northing : 22° 47'07.295"
Easting : 89° 34'51.454"
Elevation : 3.786 + P.W.D.

4.1.4 Results of the Survey

The following results are to be utilized in the course of design upon completion of the topographic survey. The outputs of survey are produced on digital basis to incorporate into CAD system:

i) Alignment layouts at a scale of 1/10,000 which show all salient features such as coordinates, length, location of beginning curve and ending of curve;

ii) Profiles along centerlines excluding Rupsa River at a scale of 1/1,000 horizontally and 1/200 vertically;

iii) Cross sections at every 50 m intervals as well as major points along centerlines at a scale of 1/200;

iv) Topographic maps at a scale of 1/200 which show all topographical features such as buildings, roads, canal, paddy dykes, fish ponds, ground elevation and boring locations; and

v) Topographic survey report which contains field notes, calculation sheets, photographs and details of the reference points, bench marks including location map, coordinates and levels during the survey works.

4.2 Soil Investigation

4.2.1 Geomorphology & Geology of Khulna region.

Bangladesh occupies major part of Bengal Basin. This Bengal Basin has been formed due to the subsection of the northeastern part of Indian plate that started in the Cretaceous period. The Bengal Basin has been evolved since the last 35 million years. Therefore It contains almost all geological sequences from Cretaceous to Present period. The major geophysical feature within the Bengal Basin is the techtonically active Hinge Zone which is extending from Calcutta to Mymensingh. This Hinge Zone divided the Bengal Basin into two parts. The one is shallow (less than 500m) shelf are a in the northwest and the other is a very deep (nearly 10km) geo-synclinal area in the Southeast (Fig. 4.2.1) The movement of Plate has been considered as the major cause of the modification of Basin Structure. The Bengal Basin is techtonically very active and it is characterised by a number of faults. It is revealed that part of the Basin has been uplifted and subside due to the result of neo-techtonic actives by geo-physical observation. Particularly in the northeastern parts of the country, in the northeastern parts of the Gange-Meghna river course, such presence of faults, neo-techtonic activities and modifications of the Basin are more remarkable than the southwestern region. Khulna city is located at the southwest region of his country. Therefore Khulna city is techtonically more stable than the rest of the country. This city has been raised and developed by the process of siltation from a network of rivers. Also Khulna city is located at the Hinge Zone. Records of deep boreholes and geophysical analysis indicate the depth of sediments above the basin floor (pre-Cambrian basement) near Khulna is about 8.5km thic. The Ganges-Brahmaputra river systems from the surrounding highlands carried the sediment which has been floored on his region. The topographic level of Khulna city is not perfectly revel and characterized by six major geomorphic units. There are natural levees, flood plains old meander complex, bar, tidal marsh and back swamps (Fig. 4.2.2). Natural levees are well developed along the Bahatrab-Rupsha banks mostly on the West bank) and is occupied mainly by the present built-up area of the city. This part of the city is 4m above the mean sea level. The proposed approach road for the Rupsa Bridge is located at the east side and west side of the Rupsha river. The approach road of east side will be situated on the Old meander complex and west side will situated at the tidal marsh land.

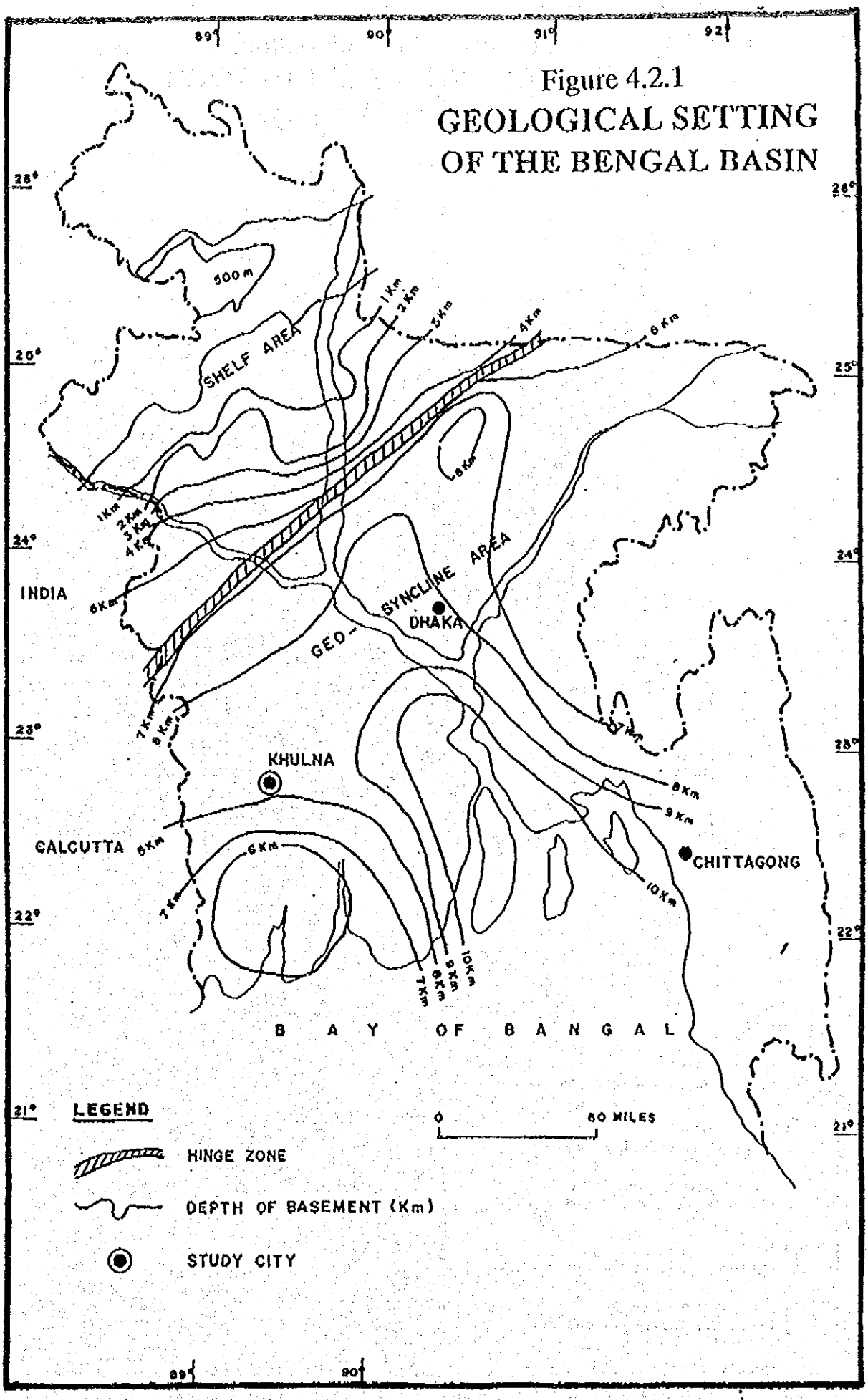
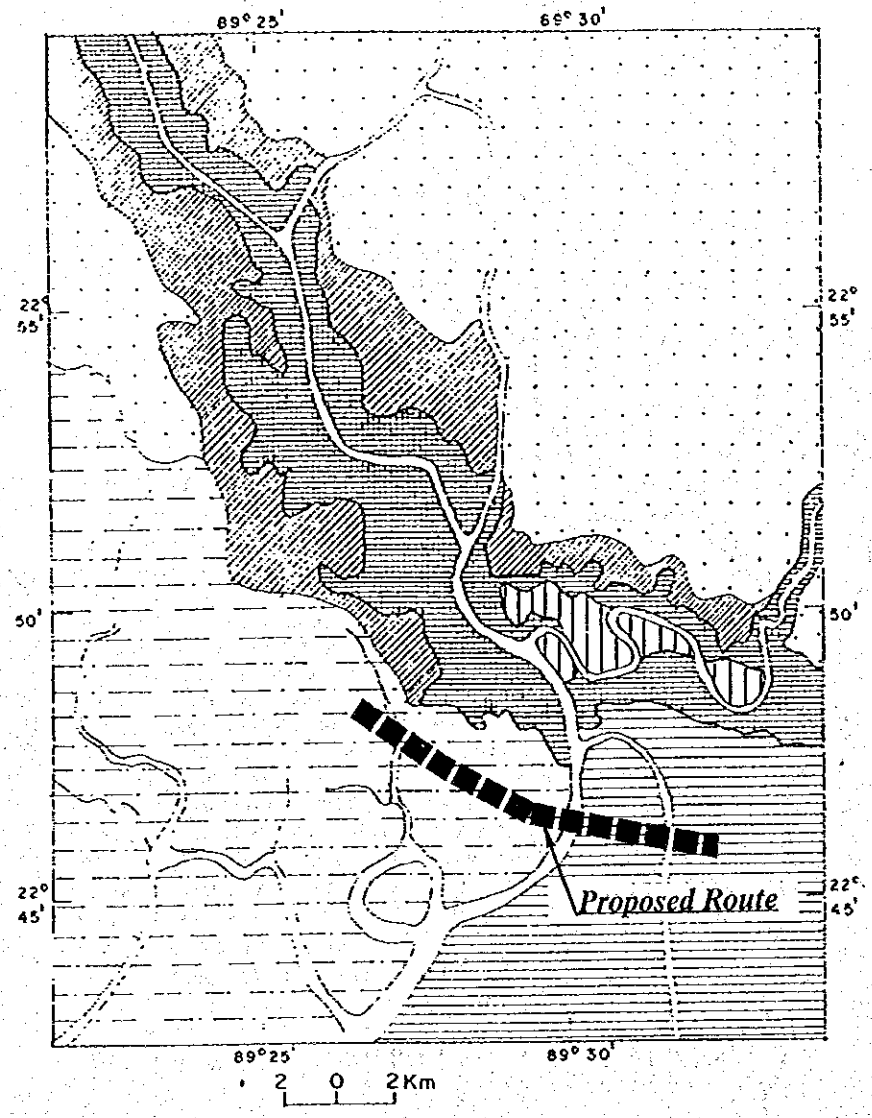


Figure 4.2.1
GEOLOGICAL SETTING
OF THE BENGAL BASIN
89°
90°
91°
92°
26°
25°
24°
23°
22°
21°
300 m
SHELF AREA
1 Km
2 Km
3 Km
4 Km
6 Km
8 Km
INDIA
GEO-SYNCLINE AREA
DHAKA
KHULNA
CALCUTTA
CHITTAGONG
7 Km
9 Km
10 Km
B A Y OF B A N G A L
LEGEND
HINGE ZONE
DEPTH OF BASEMENT (Km)
STUDY CITY
0
60 MILES

Figure 4.2.2

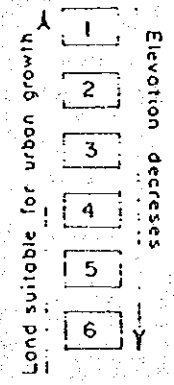
KHULNA CITY AND SURROUNDINGS
GEOLOGICAL CHARACTERISTICS & TERRAIN ELEVATION



LEGEND

1. Naturol levee. (Silty sand, Cloyey sand and Sandy silt)
2. Flood plain. (Cloyey silt and Silty cloy)
3. Old meander complex. (Sand, Silty sand and Sandy silt)
4. Bar. (Silty sand, Sandy silt and Cloyey sand)
5. Tidal marsh. (Silty cloy, Cloyey silt and Peat)
6. Back swamp. (Peaty cloy, Cloy and Peat)

TERRAIN EVALUATION



4.2.2 Contents of Ground Investigation

A Series of field investigation and laboratory tests were conducted to reveal ground conditions along the study routes. The field investigation consists of exploratory drillings with standard penetration tests (SPTs) and undisturbed soil samplings by Shelby tube, and bulk soil samplings at the ground surface. The laboratory tests were carried out on selected undisturbed and disturbed soil samples obtained from the boreholes, the bulk soil samples and aggregates which are commonly used in Bangladesh. The field investigation and laboratory tests were carried out in accordance with ASTM.

All of the factual results are presented in the "Report on Soil Investigation for the Study on Construction of the Bridge over the River Rupsa" prepared by Bangladesh Consultants Ltd. who is a contractor for the present soil investigation.

4.2.3 Drilling

A total of 37 boreholes were sunk along the proposed routes, 20 for the Route 1, 10 for the Routes 2 and 7 for the Route 3. Fig 4.2.2 shows the borehole locations. Drilling depth. varies from 24.5 to 99.3m. After submission of the Interim Report, following 8 deep boreholes were sunk at the proposed structure locations along the Route 1 ;

BH1EB2' and 1EB2"	··· 60 m deep boreholes at Hatia Bridge site
BH1EA1 and 1WA1	··· 60 m deep boreholes at Viaduct sites
BH1MP3, 1RC and 1MP6	··· 90 to 100 m deep boreholes over water at Rupsa in Bridge site

Results of the drillings together with SPT N-values are summarized in the borehole logs and presented in Appendix. Table 4.2.1 shows quantities of the drilling work performed.

4.2.4 Laboratory Tests

The selected disturbed samples obtained by the SPTs and undisturbed samples obtained by Shelby tube were subjected to following laboratory tests ;

1) Index properties tests
   Specific gravity, Moisture content, Liquid and Plastic limits, Particle size analysis, and Wet density.

Table 4.2.1 Quantities of Field Work Performed

Borehole No. or Location	*DrillingDepth (m)*	*No. of SPTs (nos)*	*Undisturbed samples (nos)*	*Bulk soil Sampling (nos)*
1VP1	49.95	33		0
1VP2	49.95	33	2	0
2VP1	49.95	33	1	0
2VP2	49.95	33	2	0
3VP1	49.95	33	1	0
3VP2	49.95	33		0
1BA1	70.95	47	1	0
1BA2	81.30	54		0
1VA1	48.45	32		0
1VA2	81.30	54		0
2BA1	60.45	40	3	0
2BA2	64.95	43		0
2VA1	64.80	43	1	0
2VA2	60.45	40		0
3BA1	60.45	40	3	0
3BA2	60.45	40	1	0
3VA1	60.45	40		0
3VA2	60.45	40	1	0
1EB1	24.45	16	1	0
1EB2	33.45	22	1	0
1EB2'	60.45	40	4	0
1EB2"	60.45	40	3	0
1EB3	24.45	16	1	0
1EB4	24.45	16	1	0
1EB5	24.45	16	2	0
1EB6	24.45	16	1	0
1EB7	60.45	40	4	0
2EB1	24.45	16	1	0
2EB2	24.45	16	2	0
2EB3	24.45	16	1	0
2EB4	24.45	16	1	0
3EB1	24.32	16	1	0
1MP3	90.38	60	1	0
1MP6	90.38	60	2	0
1RC	99.30	66	2	0
1WA1	60.45	40		0
1EA1	70.95	47	3	0
River Bank (BH1BA2)	0	0	0	3
Paddy (BH1EB4)	0	0	0	3
Rupsa River Bed (BH1BA1)	0	0	0	1
Total	1,944.78	1,286	48	7

2) Unconfined compression test

3) Consolidation tests

4) Chemical tests on organic soils
pH, Chloride, Total sulphate and Water soluble sulphate

5) Loss of ignition for organic soils

Among the above-mentioned tests ; the items 3) and 4) and wet density measurement in the index properties tests are only applicable to the undisturbed soil samples. Results of the tests are summarized in tables and shown in Appendix.

The bulk soil samples were subjected to following tests ;

1) Index property tests
Specific gravity, Liquid and Plastic limits and Particle size Analysis

2) Chemical tests
pH and Chloride

3) Compaction tests
2.5 kg and 4.5 kg rummer methods

4) California bearing test (CBR test)

Fine and coarse aggregates were subjected to following material tests ;

1) Chemical test
pH and Chloride

2) Los Angeles abrasion test

3) Alkali-Silica reactivity

Detailed test results of individual samples are shown in the factual soil investigation report. Tables 4.2.2 through 4.2.4 show quantities of the laboratory soil tests performed.

Table 4.2.2 Quantities of Laboratory Test on Samples Obtained from Boreholes

Borehole No.	Moisiture Content	Specific Gravity	West Density	Particle Size Analysis	Liquid and Plastic Limits	Unconfined Compression T.	Compolida-tion T.	Cloride	Total Sulphate	Water Soluble Sulphate	pH	Loss of Ignition
1BA1	2	3	0	3	2							
1BA2	4	2	0	2	2							
2BA1	4	2	2	3	1		1					
2BA2	1	2	0	2	2							
3BA1	4	3	2	3	1		1		1	1	1	1
3BA2	2	2	1	2	2							
1VA1	3	3	0	3	1			1	1		1	1
1VA2	5	5	0	5	4		1					
2VA1	5	5	0	5	3							
2VA2	0	2	0	2	1							
3VA1	2	2	0	2	2							
3VA2	3	2	1	2	1							
1VP1	3	1	0	2	1							
IVP2	5	1	1	2	1		1		1	1	1	1
2VP1	1	1	1	2	1							
2VP2	3	3	2	3	2		1					
3VP1	0	2	0	2	1							
3VP2	1	1	0	1	1							
1EB1	5	1	0	2	1		1	1	1	1	1	1
1EB2	1	2	1	2	2	1	1					
1EB2'	8	2	4	2	1	1	1	1	1		1	1
1EB2"	5	2	3	2	1	1	1					
1EB3	4	2	1	2	1	1	1					
1EB4	4	1	0	1	1		1					
1EB5	3	3	2	3	2	2	2					
1EB6	3	1	1	2	1	1	1					
13B7	8	2	4	2	1	1	1					
2EB1	1		1									
2EB2	2		2	1								
2EB3	2	1	1	1								
2EB4	1		1	1								
3EB1	1		1	1								
1EA1	9	4	3	4	3	2	2					
1WA1	3	2	0	2	1	1		1	1		1	1
IMP3	8	6	1	6	3							
1MP6	9	7	2	6	5							
1RC	8	6	2	6	3							
Total	133	84	40	92	55	11	17	4	6	3	6	6

Table-4.2.3 Quantities of Laboratory Tests on Balk Soil Sample

Sampling Location	Sample No.	Compaction 2.5kg (nos)	Compaction 4.5kg (nos)	Particle Size Analysis (nos)	Specific Gravity (nos)	Liquid and Plastic Limits (nos)	CBR (nos)	pH (nos)	Cloride (nos)
River Bank near BH-1 BA2	1	1	1	0	0	1	1	0	0
	2	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	0	0
Paddy near BH-1 EB4	1	1	1	0	0	1	1	0	0
	2	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	0	0
River bed (148m from BH1 BA1)	1	1	1	1	1	1	1	0	0
Total		7	7	5	5	7	7	2	2

Table-4.2.4 Quantities of Laboratory Tests on Aggregates

Sample	Particle Size Analysis	pH (nos)	Cloride (nos)	Los Angels Abrasion (nos)	Alkari-Silika Reaction (nos)
Sylhet sand	1	0	0	0	1
50mm brick chips	1	1	1	1	0
20mm brick chips	1	1	1	1	0
50mm stone chips	1	1	1	1	0
20mm stone chips	1	1	1	1	0
Coarse aggregates	0	0	0	0	5
Total	5	4	4	4	6

4.2.5 Stratification

Based on the information obtained in the present investigation, three soil profiles along the study routes are prepared and presented in Figures 4.2.4 through 4.2.6. The profiles help to understand the soil conditions at the study area. However it should be noted that it is not necessarily correct at every point in the ground. As shown in the profiles, subsurface of the study area consists of Quarternary sandy, silty and clayey deposits with varying relative density and consistency within the maximum investigated depth of 100m.

Water table measured in the boreholes was present between 0.35m and 2.75m, 0m and 2.0m, and 0.3m and 2m from the ground surface, at the Routes 1, 2, and 3, respectively.

(1) Route 1

Very soft to silty and clayey soils covers thickly throughout the Route 1 except river bed of the Rupsa River. The thickness varies from 5.5 to 16m, and a typical thickness is about 10m. The thickest point was encountered at BH-1EB2" located at east bank of Hatia river. N-value varies from 0 to 6 and the N-value of 1 to 3 predominates in this layer. Silty and clayey soils with organic matter which are weaker and more compressible than inorganic soils were observed between BH 1EB1 and BH1VA1 which are located at the west bank of the Rupsa river. Thickness of the organic soil portion varies from 3 to 7m between 1EB1 and BH1VA1. At the east bank of the Rupsa River presence of such organic soil is not distinct except at BH1VP2.

Loose to medium dense sandy soil with N-value less than 30 was encountered beneath the soft to soft cohesive soils. No sandy soil is present benece the very soft to soft soil at the Hatia river where medium stiff cohesive soil underlies the very soft silty soil.

The sandy soil layer is followed by a heterogeneous layer which consists of dense to very dense sandy soils and stiff to hard silty and clayey soils. Among the soils, silty and clayey soils predominate at the east bank of the Rupsa River as shown in Fig. 4. 2. 4.

Very dense sandy soil is thickly deposited under the heterogeneous layer. This layer will provide a competent bearing stratum for the deep foundation. The surface of this layer shows a large amount of relief as shown in Fig. 4. 2. 4. However the surface is present between PWD-50m and PWD-60m at the Rupsa River as shown in the Fig. 4. 2. 4.

The surface soil layers observed at the both sides of the Rupsa River are absent due to erosion by the river. The channel formed by the erosion has been filled

with soft to stiff silty and clayey soils and loose sandy soil.

(2) Route 2

A 5 to 16m thick very soft to soft silty and clayey soils cover over the route except river bed of the Rupsa River. Distribution of soils with organic matter is not so distinct in comparison with the other routes, Similar sediments observed at the Route 1 may be present beneath the Rupsa River bed.

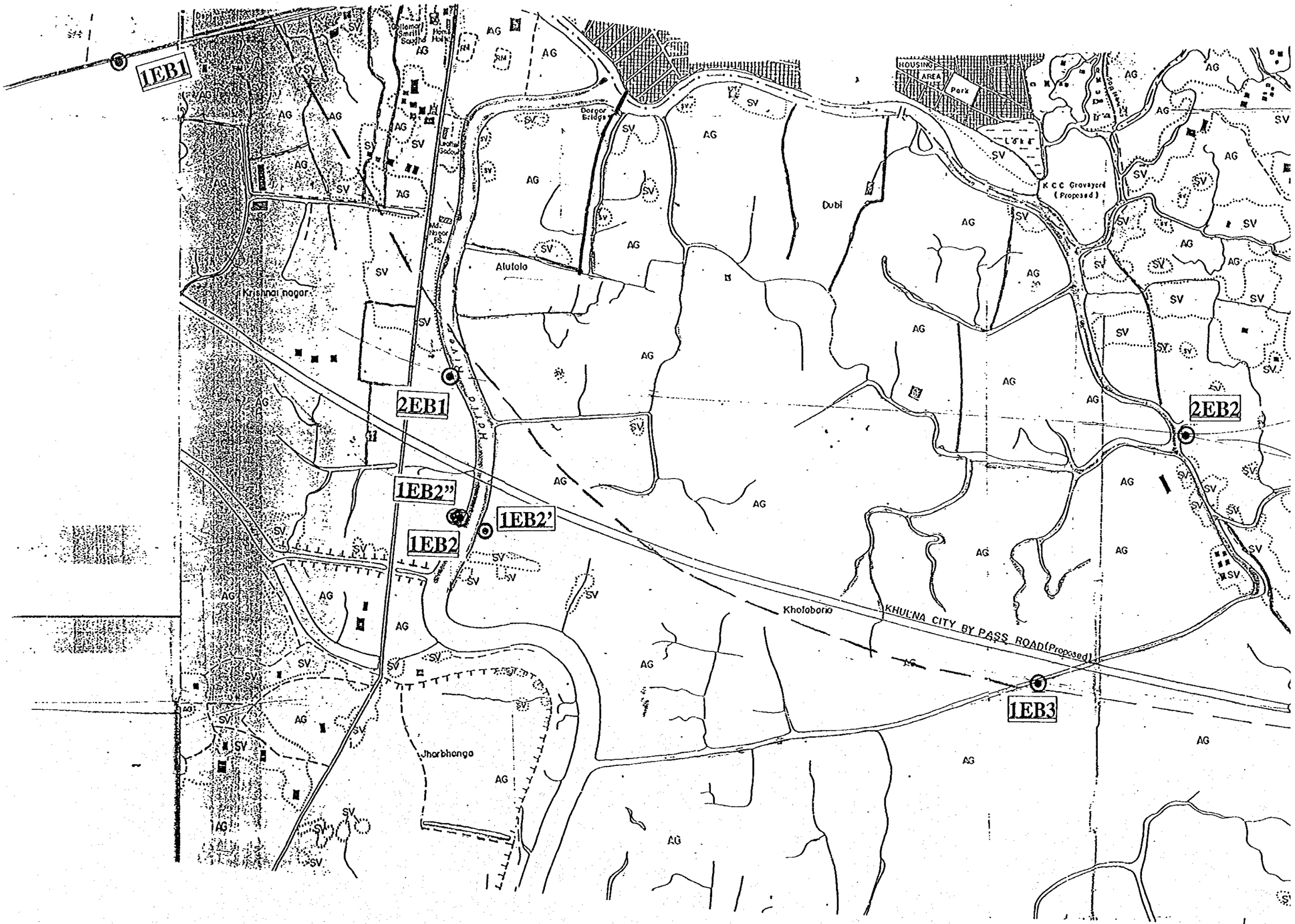
Loose to medium dense sandy soil with N-value less than 30 was encountered beneath the soft to soft cohesive soils. In the vicinity of the Rupsa River, relative density of the sandy soil increases with depth and the layer changes to a dense sandy soil layer.

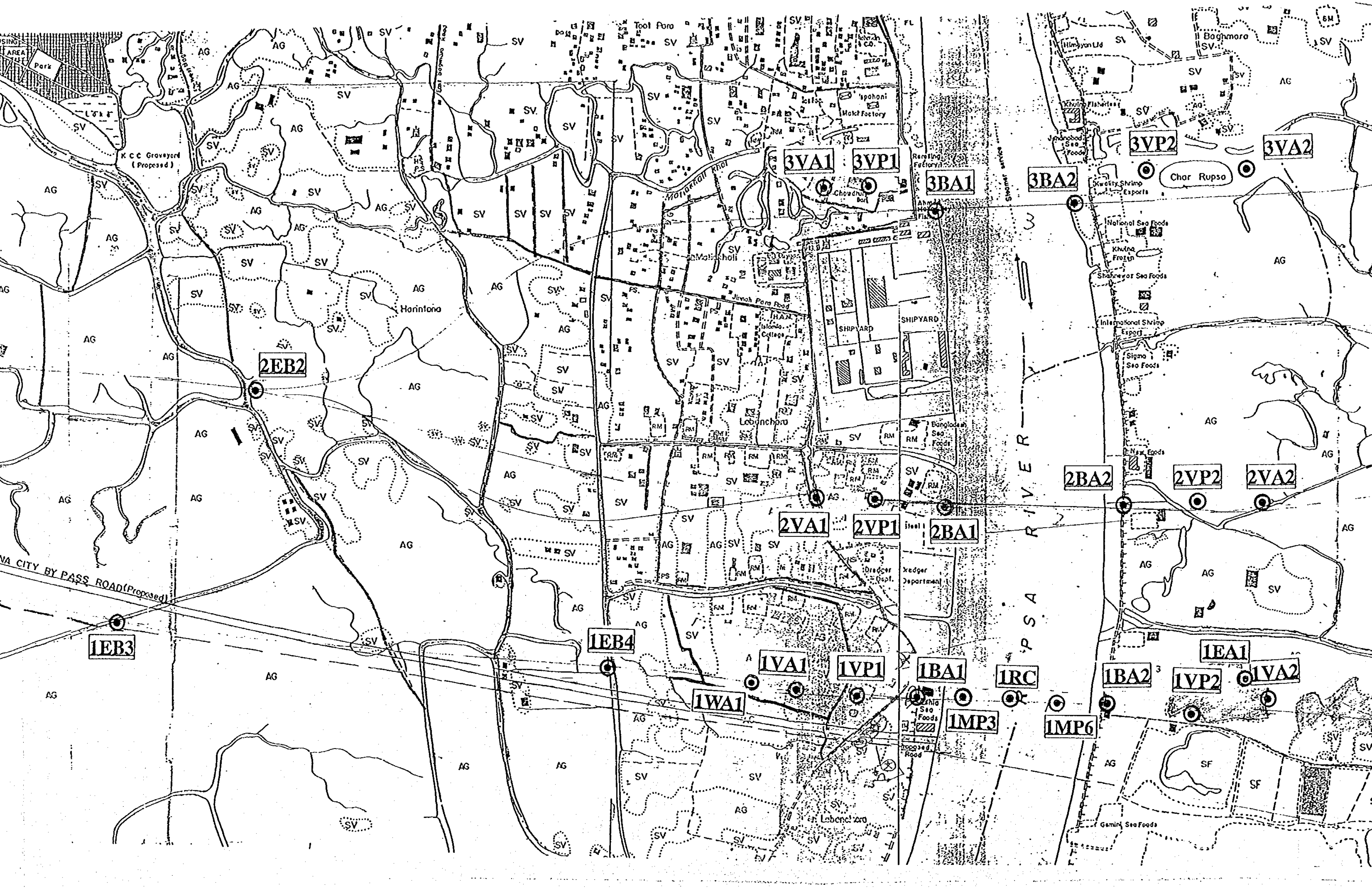
A Layer underlying the dense sandy soil layer consists of dense to very dense sandy soil and medium stiff to very stiff silty and clayey soils. The silty and clayey soils predominate at the Rupsa River. A total thickness of these soils is approximately 25m.

Very dense sandy soil layer underlies the above mentioned heterogeneous deposits. Surface of this layer lies around PWD-50m at the Rupsa River. This layer forms a competent bearing stratum for the deep foundation.

(3) Route 3

Material and stratification of the subsurface ground along the Route 3 is very similar to the Route 2. However the very soft to soft silty and clayey soils contain organic matter throughout the route, and thickness of this layer, 7 to 10m, is thinner than the Route 2. Surface of the very dense sand layer lies between PWD-48m and PWD-51m.


1EB1
2EB1
1EB2"
1EB2'
1EB2
2EB2
1EB3
Krishnai nagar
Alutolo
Dubi
Jharbhanga
Khoksboria
KHULNA CITY BY PASS ROAD(Proposed)
K C C Grovayard (Proposed)
HOUSING AREA
Park
Dorgor Bridge
AG
SV



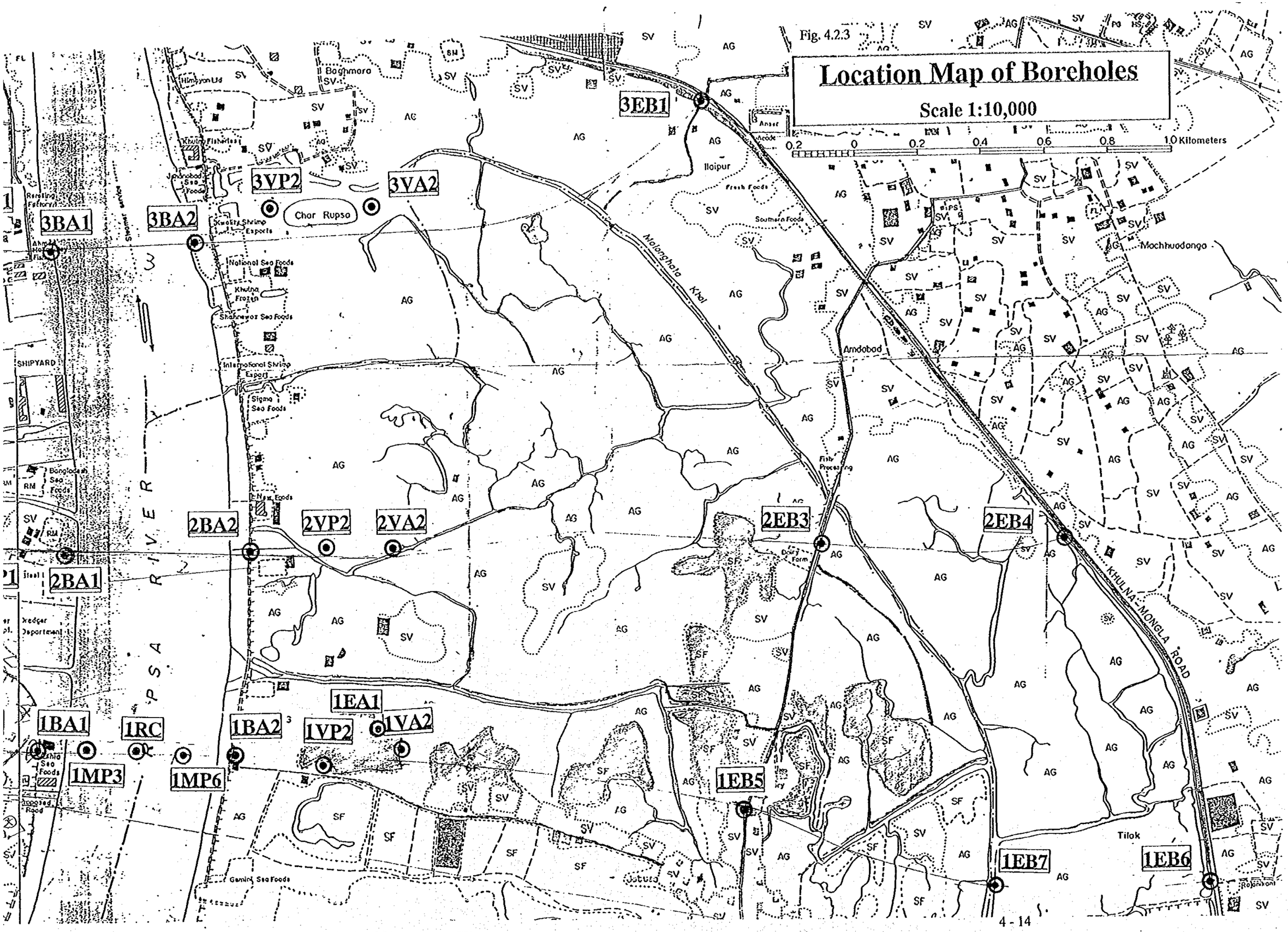
3VA1
3VP1
3BA1
3BA2
3VP2
3VA2
2EB2
2BA2
2VP2
2VA2
2VA1
2VP1
2BA1
1EB3
1EB4
1VA1
1VP1
1BA1
1RC
1BA2
1EA1
1VP2
1VA2
1WA1
1MP3
1MP6
K C C Graveyard (Proposed)
Park
Lake
Toot Para
Horintona
Mollikhali Khal
Jinnah Para Road
Lobonchora
SHIPYARD
Isphahani Match Factory
Char Rupsa
Baghmara
National Sea Foods
Khulna Frozen
Shahnewaz Sea Foods
International Shrimp Export
Signo Sea Foods
Bangladesh Sea Foods
New Foods
Gemini Sea Foods
Dredger Department
Proposed Road
RUPSA RIVER
CITY BY PASS ROAD (Proposed)

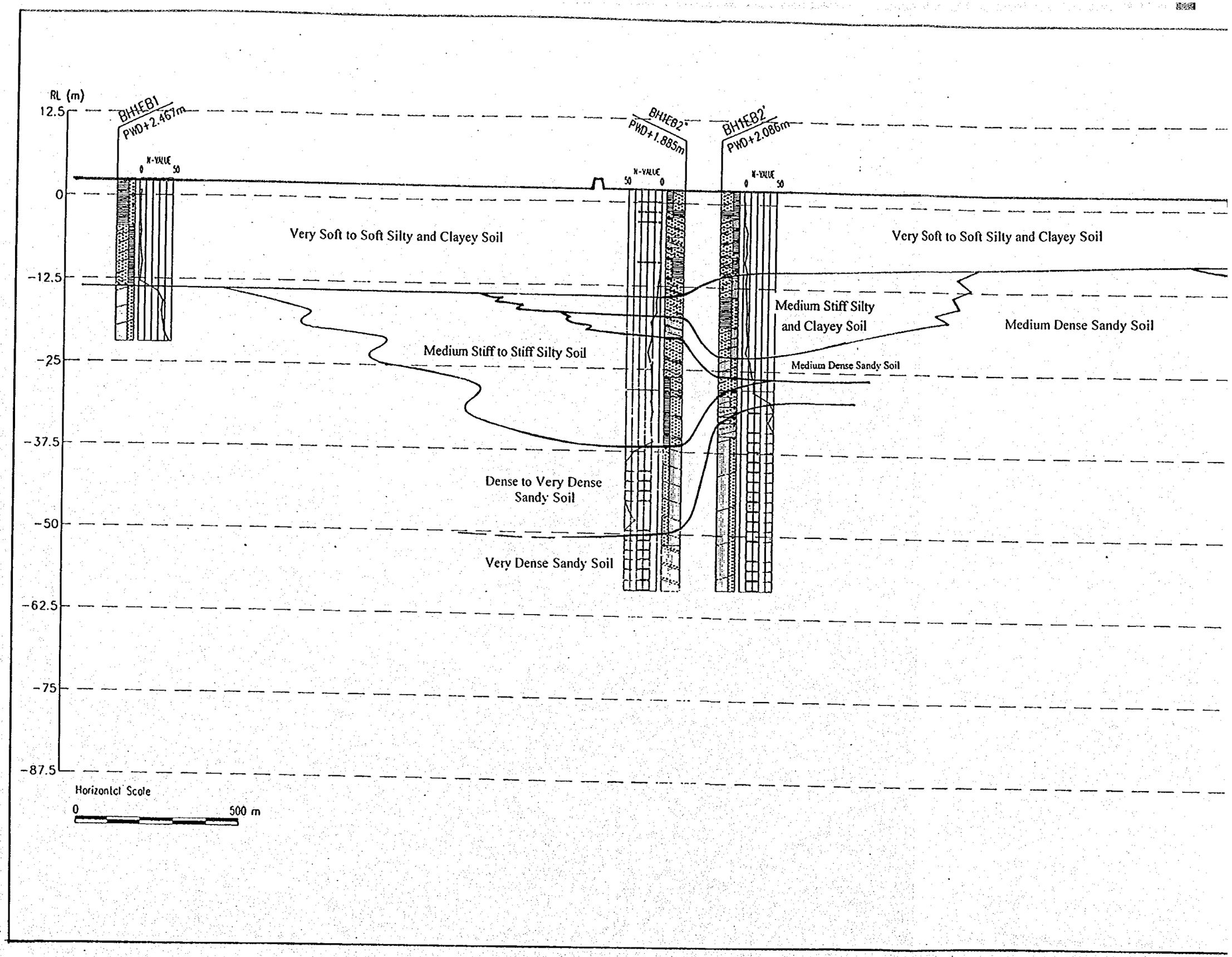
Fig. 4.2.3

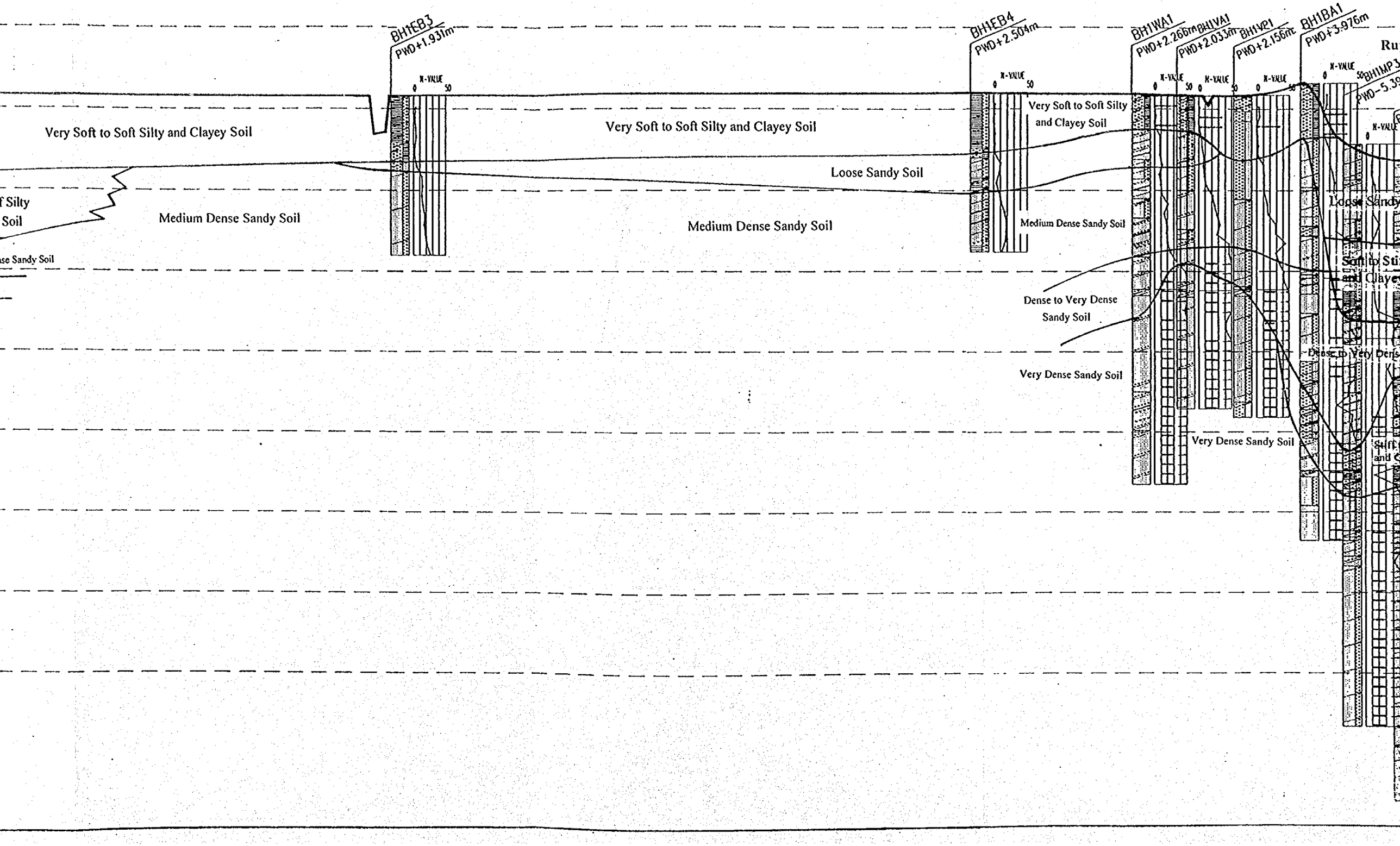
Location Map of Boreholes

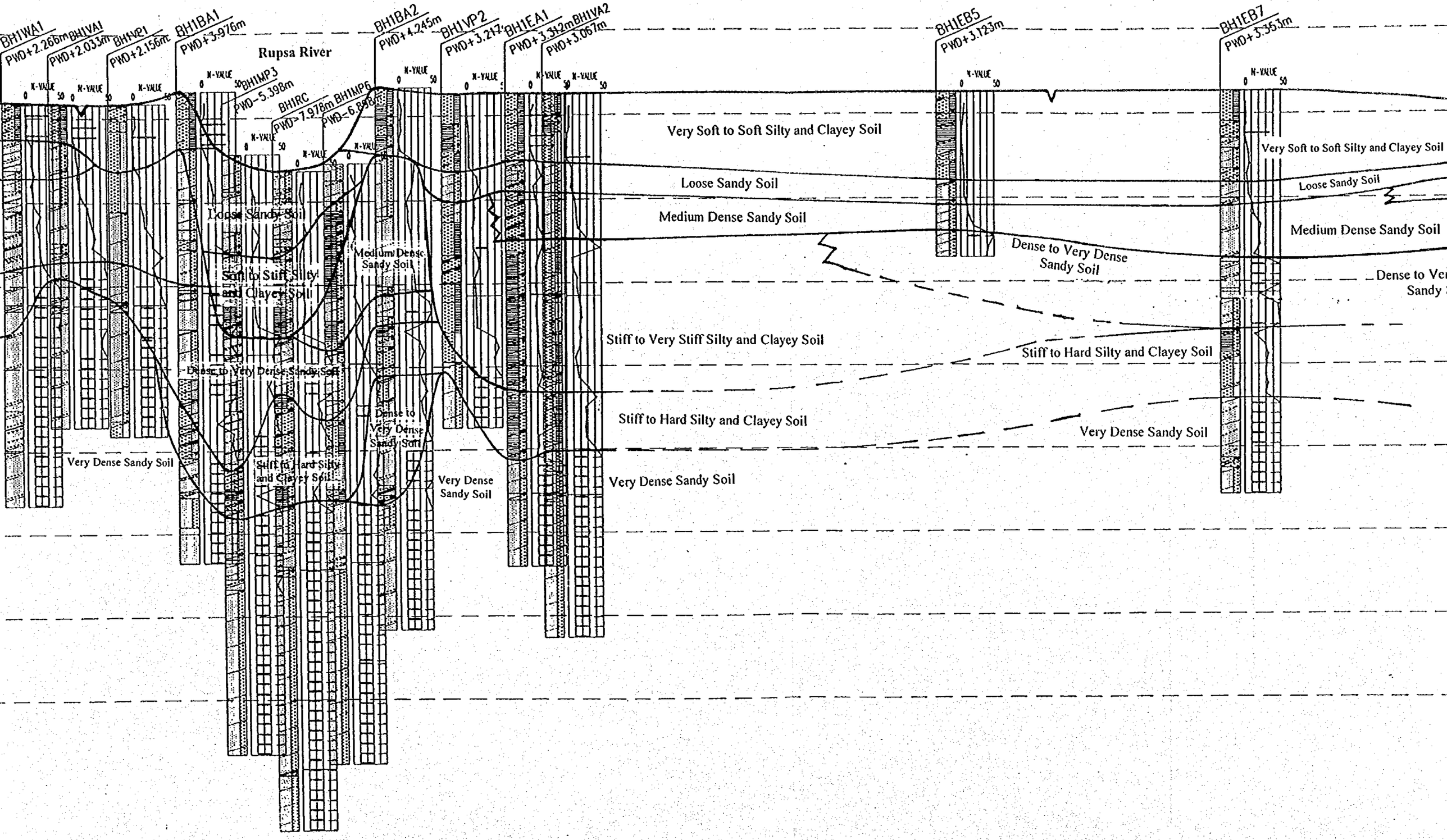
Scale 1:10,000

0.2 0 0.2 0.4 0.6 0.8 1.0 Kilometers




RL (m)
12.5
0
-12.5
-25
-37.5
-50
-62.5
-75
-87.5
BH1EB1
PWD+2.467m
BH1EB2
PWD+1.885m
BH1EB2'
PWD+2.086m
N-VALUE
0
50
Very Soft to Soft Silty and Clayey Soil
Medium Stiff to Stiff Silty Soil
Dense to Very Dense
Sandy Soil
Very Dense Sandy Soil
Medium Stiff Silty
and Clayey Soil
Medium Dense Sandy Soil
Horizontal Scale
0
500 m


BH1EB3
PWD+1.931m
N-VALUE
0
50
Very Soft to Soft Silty and Clayey Soil
Medium Dense Sandy Soil
BH1EB4
PWD+2.504m
Very Soft to Soft Silty and Clayey Soil
Loose Sandy Soil
Medium Dense Sandy Soil
Dense to Very Dense Sandy Soil
Very Dense Sandy Soil
BH1WA1
PWD+2.266m
BH1VA1
PWD+2.033m
BH1VP1
PWD+2.156m
BH1BA1
PWD+3.976m
Very Soft to Soft Silty and Clayey Soil
Medium Dense Sandy Soil
Very Dense Sandy Soil


BH1WA1
PWD+2.266m
BH1VA1
PWD+2.033m
BH1VB1
PWD+2.156m
BH1BA1
PWD+3.976m
Rupsa River
BH1MP3
PWD-5.398m
BH1RC
PWD-7.978m
BH1MP6
PWD-6.898m
BH1BA2
PWD+4.245m
BH1VP2
PWD+3.217m
BH1EA1
PWD+3.312m
BH1VA2
PWD+3.067m
BH1EB5
PWD+3.123m
BH1EB7
PWD+3.353m
N-VALUE
0
50
Very Soft to Soft Silty and Clayey Soil
Loose Sandy Soil
Medium Dense Sandy Soil
Dense to Very Dense Sandy Soil
Stiff to Very Stiff Silty and Clayey Soil
Stiff to Hard Silty and Clayey Soil
Very Dense Sandy Soil
Loose Sandy Soil
Soft to Stiff Silty and Clayey Soil
Medium Dense Sandy Soil
Dense to Very Dense Sandy Soil
Very Dense Sandy Soil
Stiff to Hard Silty and Clayey Soil
Dense to Very Dense Sandy Soil
Very Dense Sandy Soil
Very Soft to Soft Silty and Clayey Soil
Loose Sandy Soil
Medium Dense Sandy Soil
Dense to Ver
Sandy
Stiff to Hard Silty and Clayey Soil
Very Dense Sandy Soil

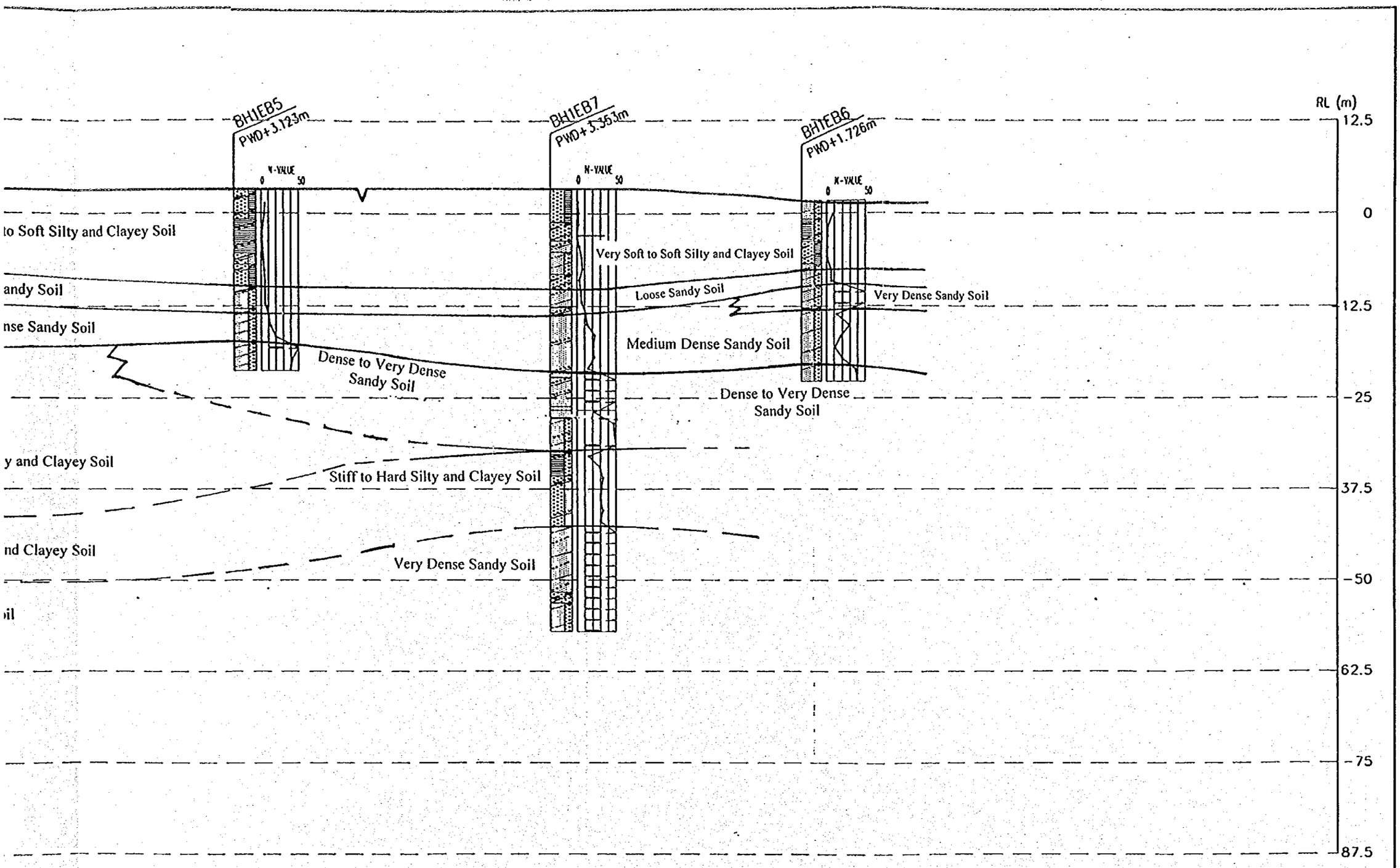
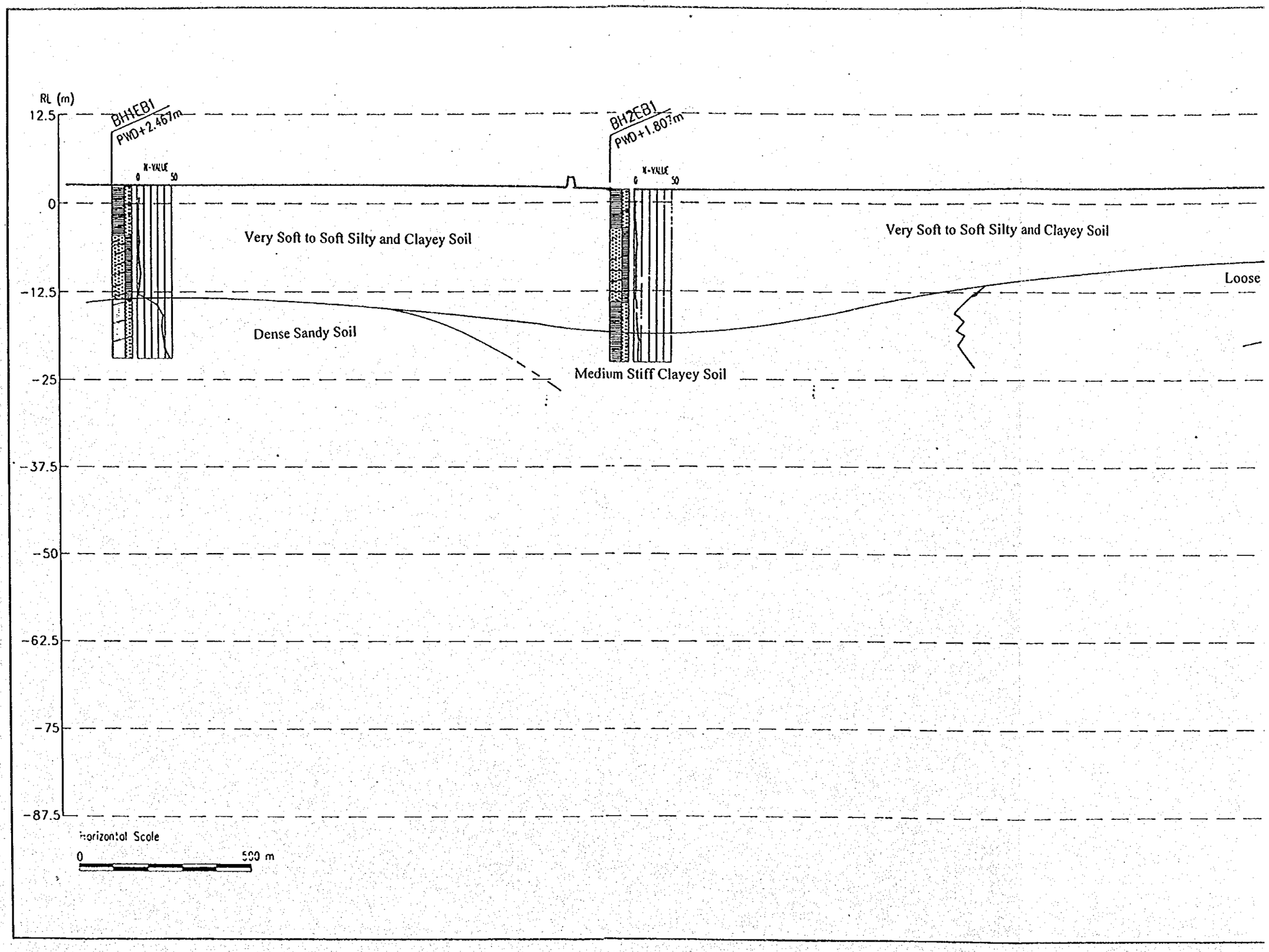
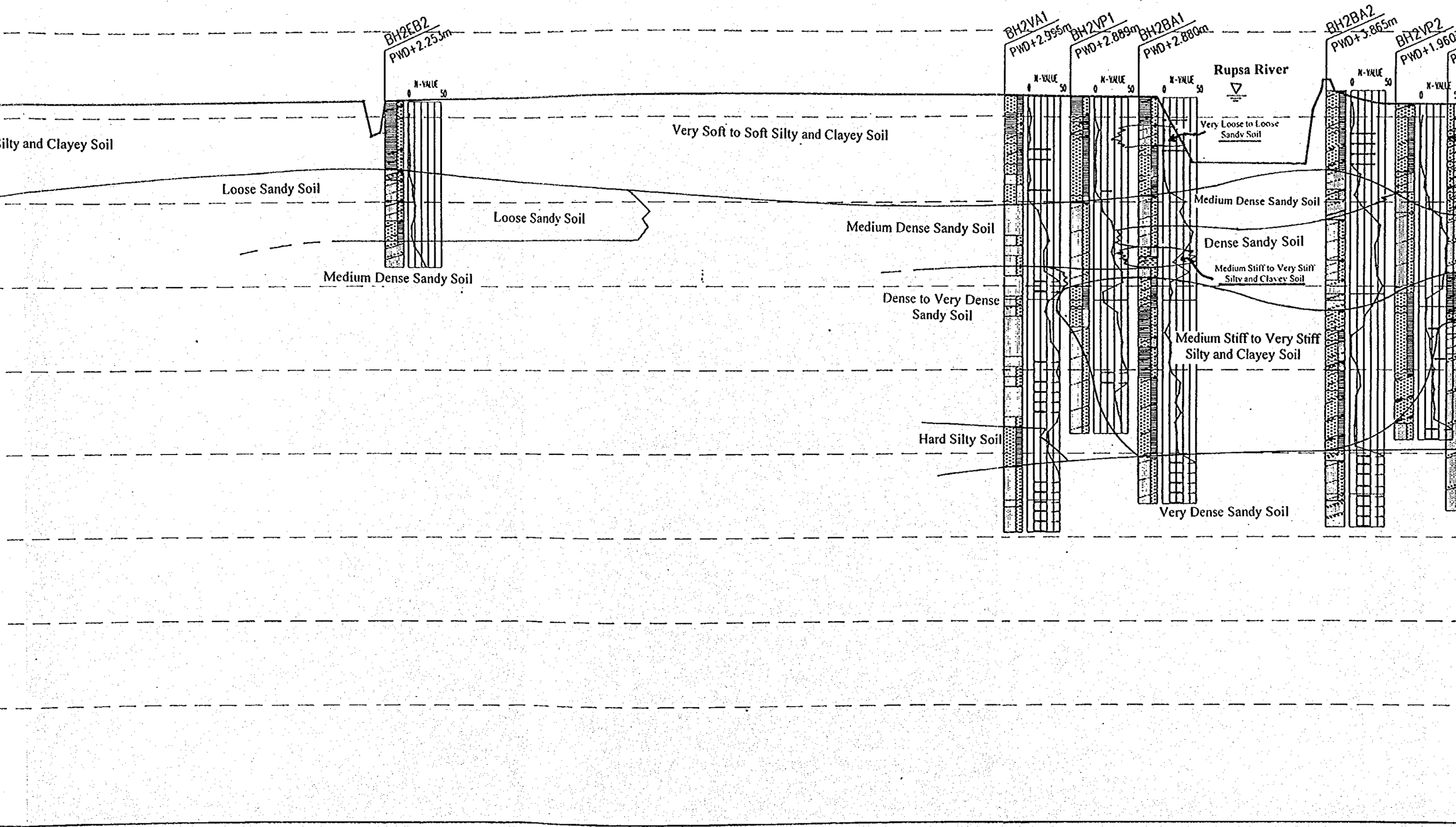


Fig. 4.2.4

JICA Rupsa Bridge Study Phase-II
Soil Profile along Route 1


RL (m)
12.5
0
-12.5
-25
-37.5
-50
-62.5
-75
-87.5
BH1EB1
PWD+2.467m
BH2EB1
PWD+1.807m
N-VALUE
0
50
Very Soft to Soft Silty and Clayey Soil
Very Soft to Soft Silty and Clayey Soil
Loose
Dense Sandy Soil
Medium Stiff Clayey Soil
Horizontal Scale
0
500 m


BH2EB2
PWD+2.253m
N-VALUE
0 50
BH2VA1
PWD+2.955m
BH2VP1
PWD+2.889m
BH2BA1
PWD+2.880m
Rupsa River
BH2BA2
PWD+3.865m
BH2VP2
PWD+1.960
Silty and Clayey Soil
Very Soft to Soft Silty and Clayey Soil
Very Loose to Loose Sandy Soil
Loose Sandy Soil
Loose Sandy Soil
Medium Dense Sandy Soil
Medium Dense Sandy Soil
Dense Sandy Soil
Medium Stiff to Very Stiff Silty and Clayey Soil
Dense to Very Dense Sandy Soil
Medium Stiff to Very Stiff Silty and Clayey Soil
Hard Silty Soil
Very Dense Sandy Soil

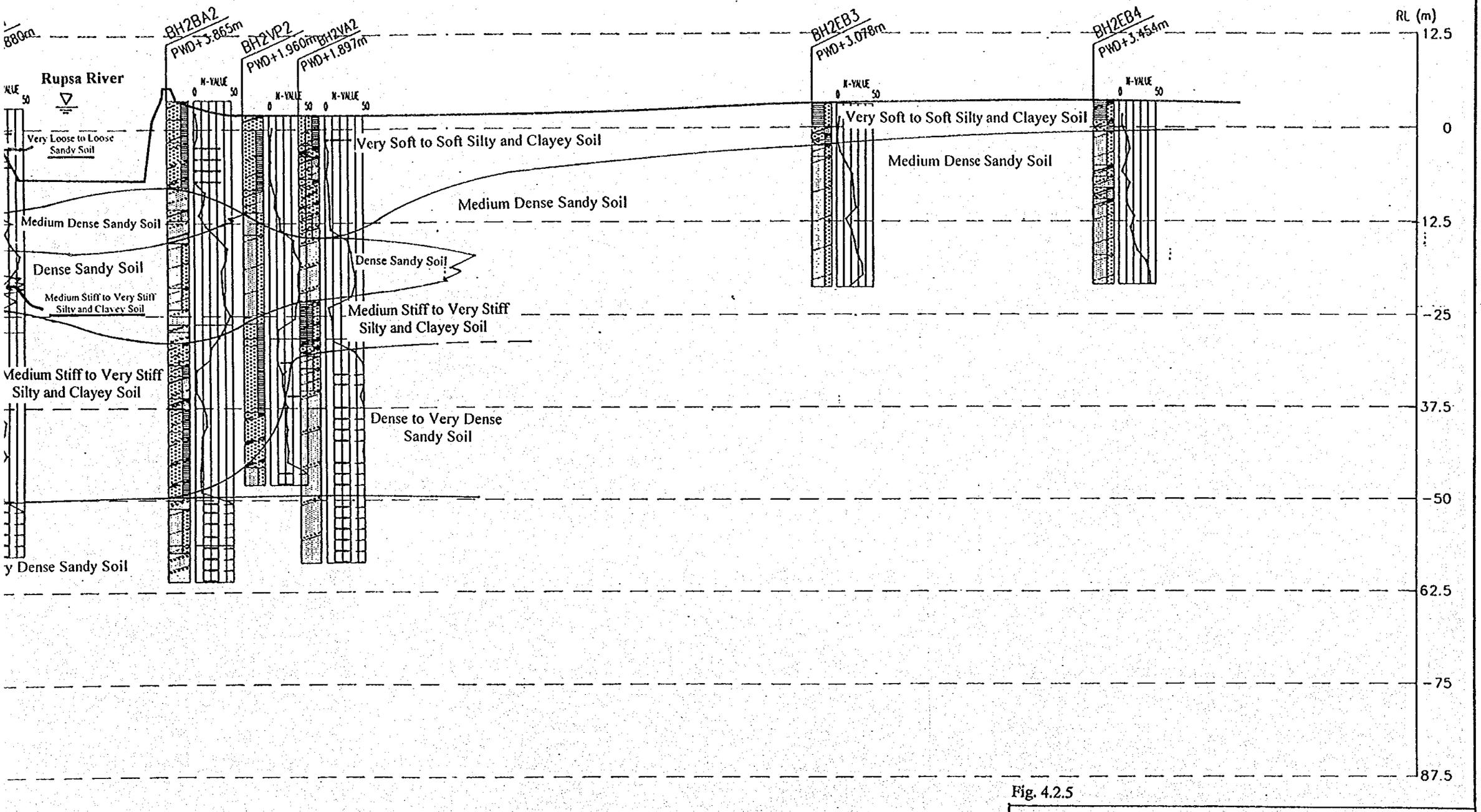
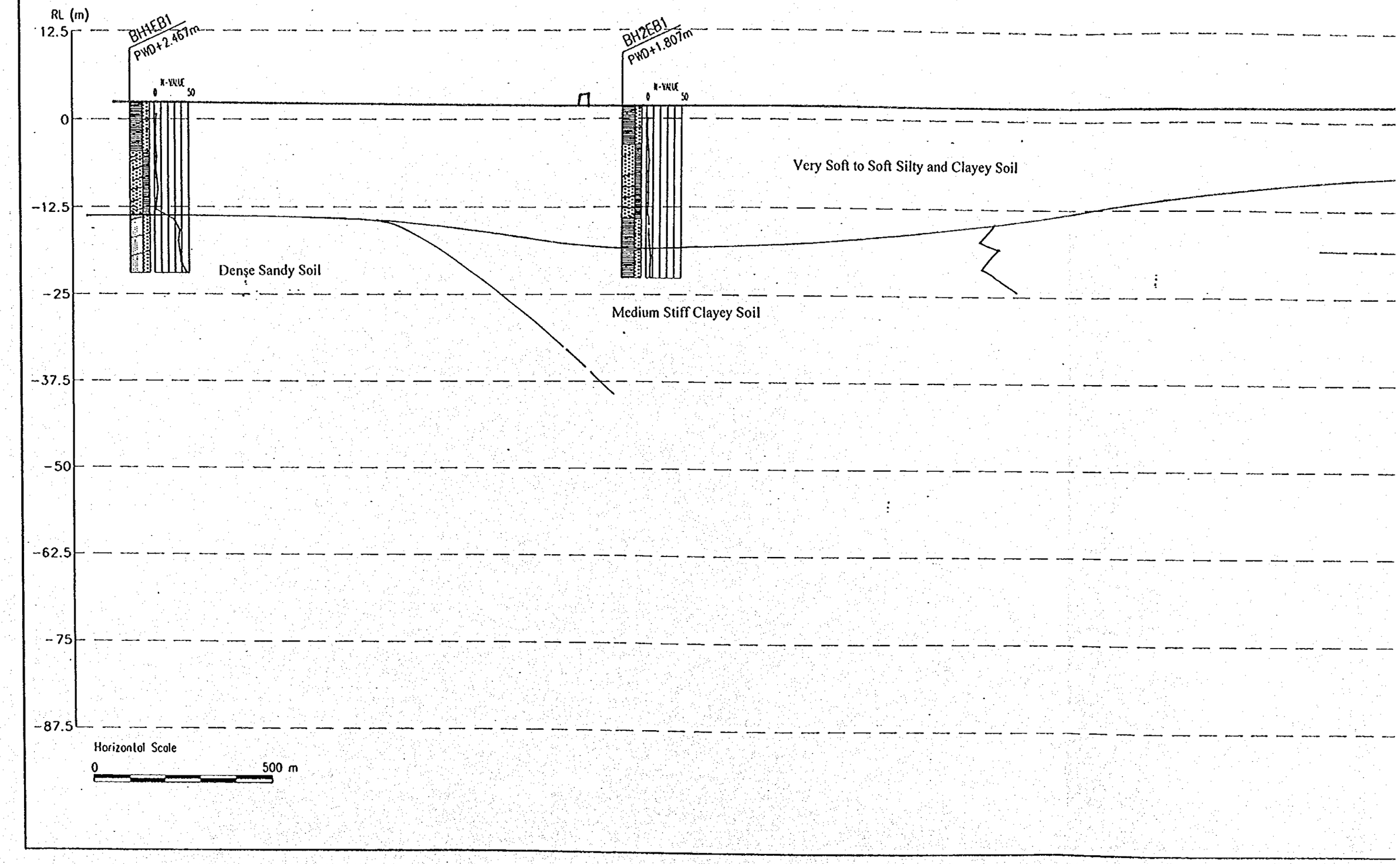
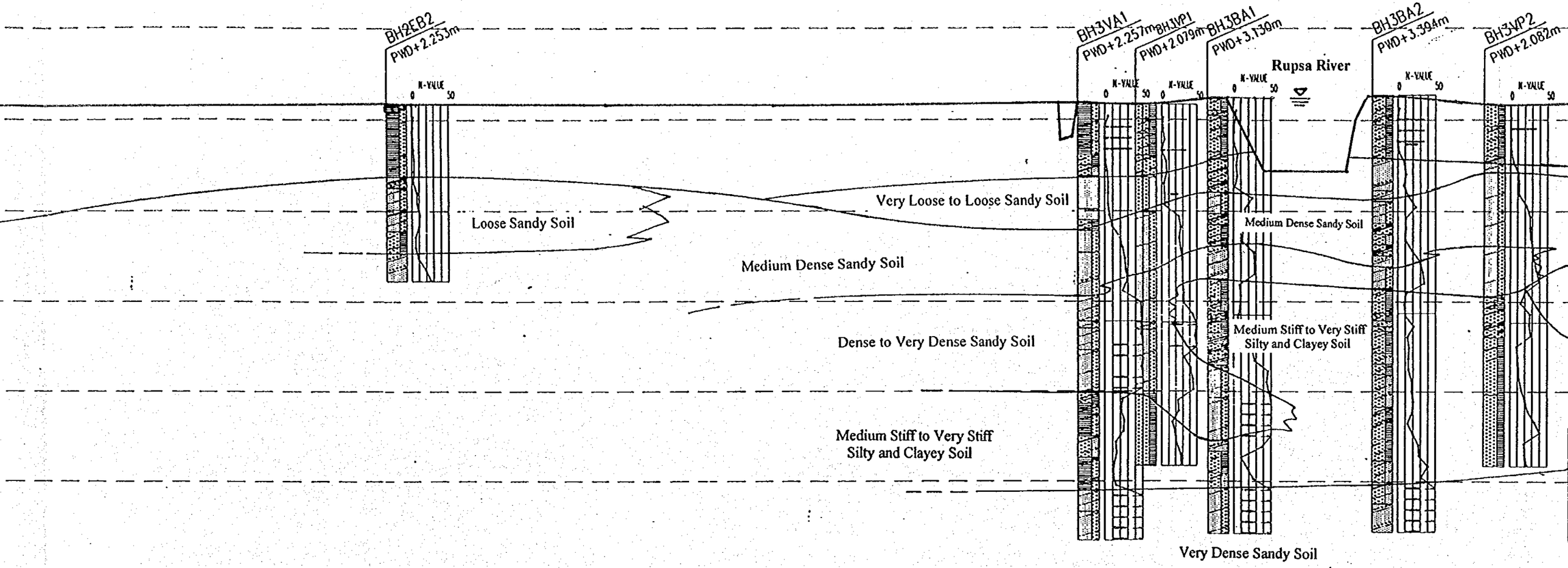


Fig. 4.2.5

JICA Rupsa Bridge Study Phase-II
Soil Profile along Route 2


RL (m)
12.5
0
-12.5
-25
-37.5
-50
-62.5
-75
-87.5
BH1EB1
PWD+2.467m
N-VALUE
0
50
BH2EB1
PWD+1.807m
N-VALUE
0
50
Very Soft to Soft Silty and Clayey Soil
Dense Sandy Soil
Medium Stiff Clayey Soil
Horizontal Scale
0
500 m


BH2EB2
PWD+2.253m
BH3VA1
PWD+2.257m
BH3VP1
PWD+2.079m
BH3BA1
PWD+3.130m
BH3BA2
PWD+3.394m
BH3VP2
PWD+2.082m
N-VALUE
0
50
Rupsa River
Loose Sandy Soil
Very Loose to Loose Sandy Soil
Medium Dense Sandy Soil
Dense to Very Dense Sandy Soil
Medium Stiff to Very Stiff
Silty and Clayey Soil
Medium Stiff to Very Stiff
Silty and Clayey Soil
Very Dense Sandy Soil

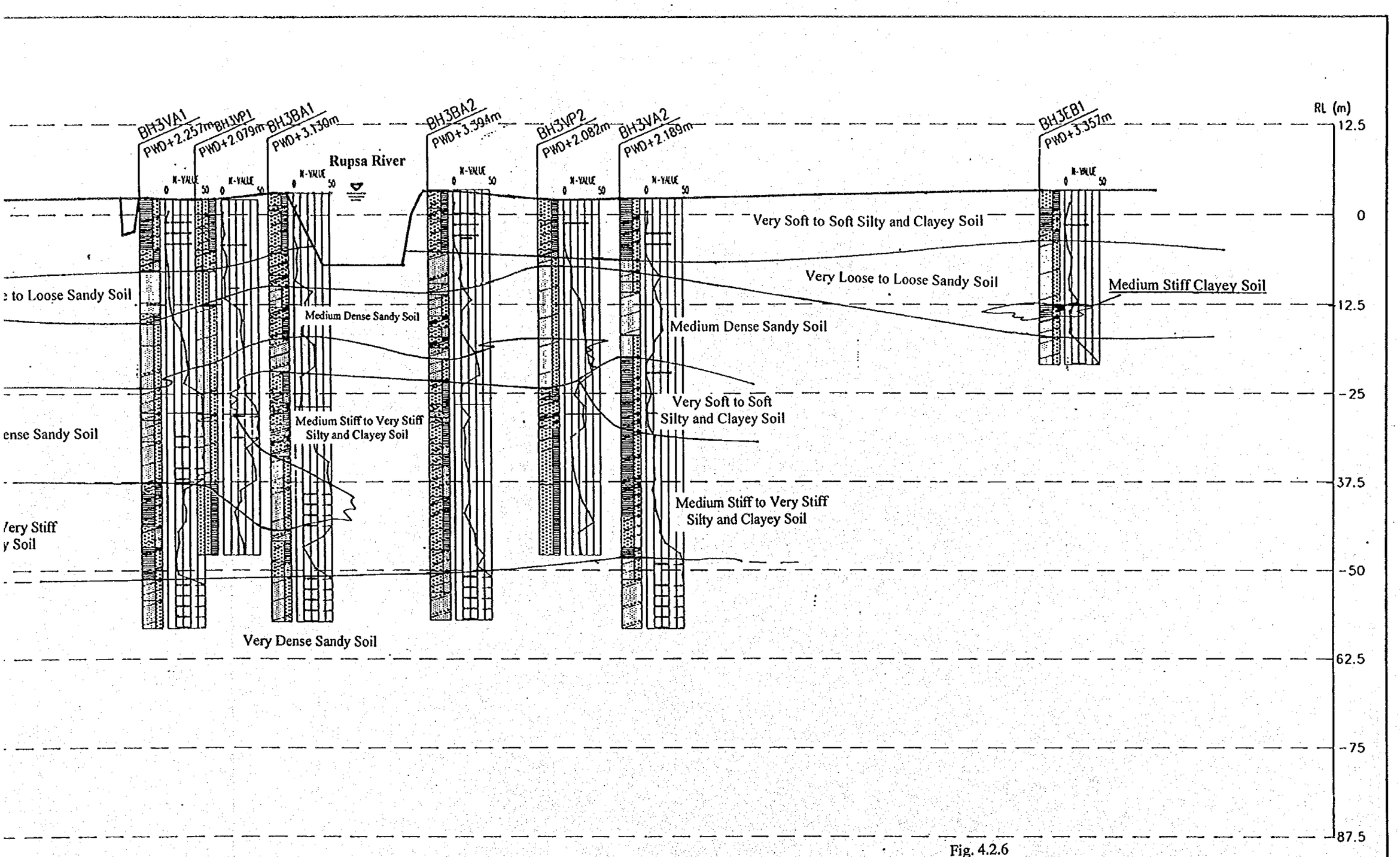


Fig. 4.2.6

JICA Rupsa Bridge Study Phase-II
Soil Profile along Route 3