PEOPLE'S REPUBLIC OF BANGLADESH

INTERIM REPORT
ON
FEASIBILITY STUDY
FOR
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

NOVEMBER 1974

JAPAN INTERNATIONAL COOPERATION AGENCY

ジャムナ河

ERRATA

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v	7	1 gal	1 gal(US)
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20	19	as follows.	as follows(See CHAPTER VII, P.174-P.177).
29	24	2022/23	2022
52	2	Bahadura bad	Bahadurabad
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100	13	bridge	bridges
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"	3 from bottom	channel	clearance
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PREFACE

At the request of the Government of the People's Republic of Bangladesh, the survey for the Jamuna River Bridge Construction Project was started under the sponsorship of the Government of Japan, and in reality embarked upon by the Japan International Cooperation Agency, formerly Overseas Technical Cooperation Agency.

Taking into consideration the importance of the project, the Japan International Cooperation Agency conducted its primary study in December 1972, and further to follow it, the feasibility study was started in July 1973 on the both sides of Bangladesh and Japan, and is to scrutinize for the period of three years in total.

As a first step, four proposed bridge construction sites were taken up to study from the standpoints of engineering and economy. In November 1974, it was then agreed upon by both Bangladesh and Japan at the meeting in Dacca to choose Sirajganj as the most suitable bridge construction site. The results of the assigned study have been recorded and compiled into the Interim Report, which is herewith presented.

Last but not least, it is my pleasure to express my heartfelt thanks to all concerns of the Government of the People's Republic of Bangladesh and its related organizations, and of Japanese Embassy in Bangladesh, and of the Government of Japan and its related organizations as well, who have kindly made their close cooperation for the successful performance of the survey.

Shinsaku Hogen

President
Japan International Cooperation Agency

November 1974

FOREWORD

It is my greatest pleasure to be able to present the Interim Report on Feasibility Study for Jamuna River Bridge Construction Project, which I owe to the close cooperation of many excellent experts of our team.

The study was carried out under the control of the Supervisory Committee for the Jamuna River Bridge Construction Project of the Japan International Cooperation Agency.

The report gives the results of studies of the first stage of this feasibility study and its primary purpose is to determine the order of priority of the four proposed sites from technical, engineering, traffic and economical points of view.

At this stage of the study, we came to a conclusion that the Sirajganj site is the most suitable one and this conclusion was agreed by the Bangladesh Delegation after the earnest discussion at the Dacca Meeting which was held in Nov. 1974.

It is scheduled that the more detailed studies will be made for the Sirajganj site according to the successive work schedule and the final report will be submitted to the Government of the People's Republic of Bangladesh through the Japan International Cooperation Agency in August, 1976.

The report consists of summary and future schedule of the study and nine Chapters. In the summary and Chapter II, I hope you will grasp the gist of the whole matter, and detailed explanations on each theme in the following seven Chapters. Various reference data and informations of the study team are appended at the end of each Chapter.

Let me allow to express my hearty thanks, on this occasion, on behalf of all the members of our team to those persons who provided us every convenience in the People's Republic of Bangladesh.

November 1974

Shizuo Inose.

Dr. Shizuo Inose,
Leader in General

The Japanese Feasibility Study
Team for the Jamuna River Bridge
Construction Project.

ABBREVIATION AND UNIT

Bangladesh	The People's Republic of Bangladesh
MOC	Ministry of Communications
BIWTA	Bangladesh Inland Water Transport Authority
MFCWRP	Ministry of Flood Control, Water Resources and Power
BWDB	Bangladesh Water Development Board
SOB	Survey of Bangladesh
Jamuna River	The Brahmaputra-Jamuna River
R & H	Roads and Highways Directorate
WAPDA	Water and Power Development Authority
JICA	Japan International Cooperation Agency
OTCA	Former name of JICA

Prefeasibility Report

Prefeasibility Report on the Jamuna River Bridge Construction Project prepared by the Preliminary Study Team of OTCA, MAR., 1973 (written in Japanese).

Inception Report

Inception Report on Feasibility Study for Jamuna River Bridge Construction Project submitted by the OTCA.

DHWL	Design high water level
GL	Ground level
WL	Water level
GWL	Ground water level below ground level
HWL	High water level
LWL	Low water level
PWD	Public Works Department
RL	Reduced level
PH	Proposed height
B	Width
H	Water depth
I	Slope
R	Mean water depth
W	River width

L,I	Length
A	Water area
Q	Discharge
v	Velocity
n	Coefficient of roughness
N	N-value, given the blow numbers of standard penetration test
LLT	Lateral loading test (or tester)
JIS	Japanese Industrial Standard
DIN	Deutsche Industrie Norm. (German Industrial Standard)
ASTM	American Society for Technical Materials
BS	British Standard
B	Diameter of foundation pile
c	Cohesion of soil
ϕ	Internal friction angle of soil
Cc	Compression index
D_{10}	Effective grain size at 10% passed
D_{60}	Grain size at 60% passed
e (or eo)	Natural void ratio
E	Elastic modulus
Em	Measured elastic modulus
Gs	Specific gravity of soil particles
H	Measured water level of tank at LLT
K	Coefficient of soil reaction, so called K-value, meaning unfied K-value
Km	Measured K-value
ko	Specific K-value
Ko	Model K-value
k	Coefficient of permeability

w	Moisture conten
WL (or Lw)	Liquid limit at Atterberg limits
WP (or Pw)	(Plastic limit at Atterberg limits (Failure pressure
P_o	Soil pressure at rest
Py	(Yield pressure at LLT (Preconsolidation pressure
P	Gauge pressure of cell water at LLT
P'	Gauge pressure of supplied gas at LLT
P_G	Reaction of rubber, given H-Pg curve at LLT
Ps	Static water head
Pe	Effective pressure at LLT
C	Coarse } in case of grain size
F	Fine } in case of grain size
M	Medium } in case of grain size
C	Clay } in case of soil classification
M	Silt } in case of soil classification
S	Sand } in case of soil classification
U	Undisturbed sample
D	Disturbed sample
γt	Wet density
γd	Dry density
qu	Unconfined compression strength
E50	Elastic modulus at 50% strained, given uncofined compression test
ε	Strain at failure, given unconfined compression test
ν	Poisson's ratio
y	Displacement of pile
rm	Hole rudius for calculation at LLT, given result chart
	Initial hole radius at LLT

m	meter
s,sec	second
cm	centimeter
mm	millimeter
km	kilometer
g,gr.	gram
kg	kilogram
lb	pound
t, ton	ton (metric)
f, ft,(')	foot
m^3/s	cubic meter per second
cfs	cubic foot per second
gal	gallon
in,(")	inch
yd	yard
mi	mile
ac	acre
hr	hour
mon	month
yr	year
sq	square
cu	cubic
max.	maximum
min.	minimum

1 in = 2.54 cm

1 ft = 0.305 m

1 yd = 0.914 m

1 mi = 1.609 km = 5,280 ft

1 sq. ft = 0.0929 m^2

1 cu. ft = 0.0283 cub. m

1 gal = 0.0038 cub.m

1 lb = 0.453 kg

1 cfs = 0.0283 m^3/s

1 ac = 0.4 ha = 0.004 sq. km

1 in/mi = 1/63,360

1 ft/mi = 1/5,280

TK 1 = ¥36

CONTENTS

SUMMARY AND FUTURE SCHEDULE OF THE STUDY

The feasibility study for the Jamuna River Bridge Construction Project was started from July 1973 and the first stage of the study which was scheduled in the Inception Report has now finished.

The summary and future schedule of the study are as follows.

1. Summary.

(1) The Preliminary Study Team proposed the following four sites for the Jamuna River crossing on the stretch of the river between Bahadurabad and Aricha, namely,

- downstream of Bahadurabad,
- near Gabargaon,
- about 10 km (6 miles) downstream of Sirajganj and
- about 20 km (12 miles) upstream of Aricha.

The main purpose of the first stage of this study is to determine the order of priority of the above-mentioned four sites according to the next criteria which was described in the Inception Report, namely

- stability of the river channel,
- traffic volume to be expected in the future and
- costs of construction.

The studies were carried out with regard to the railway-cum-highway bridge at each of the four proposed sites and according to the results of these studies, we wish to propose the Sirajganj site as the most suitable one for the Jamuna River crossing. At this site, the Dhaleswari crossing is included in the railway and highway access. The study of this crossing was also taken into consideration.

The study relating to the bridge site is described in Section 10 of Chapter II.

(2) In our judgement, the construction of the bridge across the Jamuna is technically feasible.

(3) The determination of the effective width of the Jamuna Bridge is one of the most important matters in this project, because it depends largely upon not only future overland transport in the People's Republic of

Bangladesh but also total cost of construction.

Considering the results of economic and traffic study of our team and referring to the Report of the Bangladesh Transport Survey, the following two cases were studied.

Case A.

Railway part:	Single broad gage track
Highway part:	Two-lane carriageways of total width 24 ft.

Case B.

Railway part:	Double broad gage tracks
	Four-lane carriageways of total width 48 ft.

But, we propose an effective width required for single broad gage track (5' 6") and two-lane carriageways of total width 24 feet, because it is presumed that the traffic capacity of this width will meet the volume of traffic to be expected for more than fifty years hereafter.

(4) For the purpose of river training, guide-bank system was introduced in order to make flood flow run through the definite channel and three types of guide banks were considered at each of the four proposed sites.

In selecting the river width for the bridge, it is most desirable to take a width larger than the present state, or it is undesirable to narrow the present one in view of future possible increase in discharge which will generally take place as river improvement works go forward and considering future river plans as well as future possible change in river bed and other regime.

But even if the river may be narrowed for some reasons, it should be more than about 4000 m (2.5 miles).

(5) It is expected that large volume of pitching stones will be needed for protecting guide banks and bridge piers from scouring. Therefore, the unit cost of pitching stone is one of the most important element which governs the total cost of construction of this project.

If preferable new sources of stone were to be developed within the territory of the People's Republic of Bangladesh, the cost of construction could be considerably reduced. The development of preferable quarry is not only necessary for this project but also important to the construction in general within the country.

Therefore, we recommend that the development of preferable quarry should be undertaken as soon as possible.

2. Future Schedule of the Study.

For the most suitable site to be decided finally, the following studies are scheduled to be made from November 1974 to August 1976. The work schedule is shown by bar chart attached herewith (see APPENDIX III).

(1) Surveying.

At the second stage of this study, a new surveying will be carried out attaching importance to the bridge axis at the most suitable site. General feature of the surveying is as follows.

1) Aerial photographing and photo processing.

2) Establishment of control points to be used for topographic mapping and river cross-sectional surveying.

3) Leveling for topographic mapping and river cross-sectional surveying.

4) Sounding.

5) Observation of water level of the Jamuna River.

6) Cross-sectional surveying of rivers other than the Jamuna which will be bridged over by the railway and highway accesses.

These works are scheduled to be done during the coming dry season.

(2) Geological study.

Geological study of subsurface by means of test drilling will be performed along the center line of the bridge at the most suitable site. Five drillings of 300 to 400 feet depth are scheduled during the coming dry season.

The following mechanical tests in site and laboratory will also be performed during drilling work.

1) Standard penetration tests at every 10 ft depth interval in each hole.

2) Several times of lateral-load tests in each drilled hole.

3) Physical and mechanical tests on samples taken at drill holes.

(3) Quarry study.

Recently, we got some informations about the stone source at the Madhyapara region of Dinajpur district. Our study team wish to perform the detailed study for this stone source in the dry season between November 1974 and March 1975. And, so far as circumstances permit, the reconnaissance is also scheduled to be carried out for the quarry along the Ganges River in the vicinity of West Bengal, India, in this dry season.

(4) Study of river planning.

The following studies with regard to the most suitable site are scheduled to be made on the basis of the results of surveying and geological study.

1) Planning of river training works.

2) planning of construction works.

(5) Study of bridge planning.

The following studies with regard to the most suitable site are scheduled to be made on the basis of the results of surveying, geological study and study of river training.

1) Planning of bridge.

2) Planning of construction works.

(6) Traffic survey.

The study on transportation is scheduled to be continued also at this stage.

(7) Benefit cost analysis.

The following studies with regard to the most suitable site are scheduled to be made on the basis of the results of various studies concerned.

1) Estimation of benefits.

2) Estimation of total cost.

3) Benefit-cost analysis.

(8) Final report.

Prior to submitting the final report, the study team shall prepare the draft final report for discussion with the Government of the People's Republic of Bangladesh.

After the discussion on the draft final report, the team shall prepare the final report and submit to the Government of the People's Republic of Bangladesh through the JICA.

ACKNOWLEDGEMENT

We should like to acknowledge for the continuing assistance and cooperation of the Ministry of Communications and other authorities concerned of the Government of Bangladesh.

CHAPTER I

INTRODUCTION

The Brahmaputra River is one of the largest rivers in the world. It rises on the northern slopes of the Himalayan Mountains in Tibet, traversing the Himalayas in the eastern part, flows through the Assam Plain, and then enters into the land of the People's Republic of Bangladesh.

After joining with the tributaries Dharla and Tista, it flows almost to the south. It is known as the Jamuna River until its confluence with the Ganges River near Aricha. Then it changes the name to the Padma River and goes down to the southeast about 100 km (63 miles) and after joining the Megna River near Chandpur, pours into the Bay of Bengal.

The land of the People's Republic of Bangladesh is divided by the Jamuna River into the eastern and western parts. At present, there are no bridges across the Jamuna River. All passengers and freight traffic across the Jamuna utilize ferries. This takes a lot of time. Absence of bridge is one of the major causes for hindering development of the People's Republic of Bangladesh.

Therefore, the construction of the Jamuna Bridge will be sure not only to promote growth of east and west communication but also to be useful for the development of the People's Republic of Bangladesh.

After the liberation in 1972, the Government of the People's Republic of Bangladesh requested to the Government of Japan to assist in making a feasibility study for the construction of bridge over the Jamuna River. The Government of Japan acceded to the request and has entrusted the execution of study to the Japan International Cooperation Agency (hereinafter called the JICA, former the OTCA).

According to the acceptance of the Government of Japan, the JICA organized the preliminary survey team headed by Mr. Ishio Kawasaki, and sent the team to the People's Republic of Bangladesh.

The preliminary survey team visited to the People's Republic of Bangladesh from the end of Nov. to the end of Dec., 1972 and carried out necessary studies relating to this project.

After homecoming, the team submitted a preliminary survey report to the JICA. The team reported that the necessary period for performing this study is expected to be about three years.

Based on this report, the JICA decided to make a feasibility study of this project from 1973 to 1976. In May 1973, the JICA established the Jamuna Bridge Survey Office at Dacca, Branch Office at Sirajganj and nominated Mr. Junji Ebihara for the director of this Office. In June 1973, the JICA organized the Japanese Feasibility Study Team for the Jamuna River Construction Project and appointed Dr. Shizuo Inose to the leader in general of this Feasibility Study Team. In July 1973, the Inception Report was presented by the JICA to the Government of the People's Republic of Bangladesh.

As the project includes many special engineering problems, the Study Team has been composed of six special engineering groups. The six special groups are as follows.

Surveying Team headed by Mr. M. Kikuchi.
Geological and Quarry Survey Team headed by Mr. M. Sakaita.
River Planning Team headed by Dr. S. Sato.
Economic and Traffic Study Team headed by Dr. Y. Yanai.
Railway and Highway Planning Team headed by Mr. K. Yoshie.
Bridge Planning Team headed by Mr. K. Tezuka.

The JICA began to perform the study of the project in accordance with the Inception Report. As described in the Inception Report, the study is divided into two stages.

The main purpose of the first-stage study is to determine the order of priority of the four proposed sites taking the three criteria which was described in the Inception Report into consideration. Now such studies were finished and the Interim Report has been prepared.

In Sept. 1974, the Tokyo Meeting was held under the auspices of the JICA.

The main purpose of this meeting is to explain the present state of progress of this feasibility study to the delegation of the government of the People's Republic of Bangladesh in order to deepen mutual understanding of the study and to promote the future study smoothly.

There were many discussions with regard to the agenda attached herewith which was prepared by the JICA. We could obtain many fruitful results to promote the future study. The results of discussion at the Tokyo Meeting were taken into consideration in the progressing studies.

After the most suitable site has been decided in consideration of the results of the Interim Report, the second stage of the study is scheduled to be commenced immediately.

At the second stage of the study, more detailed studies will be performed for making the plan at the most suitable bridge site including benefit-cost analysis.

CHAPTER II

OUTLINE OF STUDIES

Since the Japanese Feasibility Study Team for the Jamuna River Bridge Construction Project entered upon the work in the year of 1973, about one and half years have run their course. The team has up to now carried out various studies at field or at home office and the studies are progressing in accordance with the prearrangement and partly taking the results of discussion at the Tokyo Meeting into consideration.

The Interim Report is to be presented by the JICA to the Government of the People's Republic of Bangladesh at the beginning of December 1974.

The summary of works which were carried out by the team will be described below.

1. Surveying.

The main purpose of this work is to survey the Jamuna River at flood state and to obtain data required for designing the bridge and planning the river training works.

The surveying works were carried out by twelve experts at the four proposed sites from July to Nov. 1973. The surveying in the rainy season was carried out using the special surveying boat sent from Osaka, Japan. The surveying works were as follows.

(1) Cross-sectional surveying of the river.

Cross sections of 71 in number were surveyed at the four proposed sites. The interval of cross sections was about 2 km (1.25 miles) at the Bahadurabad site and the Gabargaon site and about 1 km (0.63 miles) at the Sirajganj site and the Nagarbari site. Supplementary soundings were carried out at each of the proposed site.

(2) Measurement of velocity and direction of flow.

Velocity and direction of flow were measured at depths of 0.5 m (1.64 ft), 1 m (3.28 ft), 2 m (6.56 ft) and after that at regular intervals of 1 m until 10 m (32.8 ft) below the water level. Thereafter, the measurement was performed at intervals of 2 m until arrived at the river bed. This measurement was done at interval of 500 m (0.8 miles) across, the entire width of the river at each of the four proposed sites.

(3) Collection of data on water level.

Data on water level from 1st. Sept. to 31st. Oct., 1973 which were collected by the BWDB were obtained. These data were applied to the analysis of water depth of the Jamuna River.

(4) Data on water level at 20 observation stations were collected.

2. Geology.

The geological investigation party has made comparison of geological situation of the four proposed sites based on the test drillings performed at one spot at each site to the depth of 300 to 400 feet.

Base rock, consisting of the Tertiary sedimentary rocks and other Pre-tertiaries, are remarkably subsided in the land of the People's Republic of Bangladesh as the result of the Himalayan orogenesis and these base rocks are located very deep under the Quaternary deposit, except in a part in the eastern area of the country where the Tertiary rocks are cropped out. The Pleistocene deposit overlying the above is extensively eroded by river flows in the period of late Pleistocene regression and is found in deeper portion more than several tens of meters below the ground surface at the present, except in Barind Hills around Maduhpur and other places. Filling above ancient valleys of the glacial ages, the Alluvial deposit covers the greater part of the area.

In Fig. 2-1, the AL and its upper strata are Alluvial, and the underlying are Diluvial. The strata appropriate for the foundation of heavy structures in the aspect of bearing strength are found in the lower Alluvium and Diluvium. Consequently, the foundation of piers will be deeper than 50 meters (164') at each site even if scouring in flood season is not taken into consideration. And the upstream site seems more preferable geologically than the downstream.

The Alluvium, mainly composed of fine to medium sand in the most part, shows higher density in deeper portion, grain size of sand also increases with the depth but this tendency is not very remarkable.

The diluvium deposit, composed of fine to medium sand alternated with thin gravel layer and soft shale, has high density and is deemed to have sufficient bearing strength. However, the part of fine to medium sand is not so resistive against scouring due to its poor cementation.

The following table shows the comparison of foundations at the bridge sites made from only geological point of view.

Comparison of foundations at the proposed bridge sites.

	Depth of stratum with N-value more than 100	Depth of resistive stratum against scouring
1 (Bahadurabad)	55 m (180')	over 92 m (300')
2 (Gabargaon)	60 m (197')	81 m (266') soft shale
3 (Sirajganj)	73 m (240')	73 m (240') gravel bed
4 (Nagarbari)	85 m (279')	85 m (279') gravel bed

Note: 1. At site 3, if the gravel bed is discontinuous, the next resistant bed against scouring is located at 103 m (338') in depth.

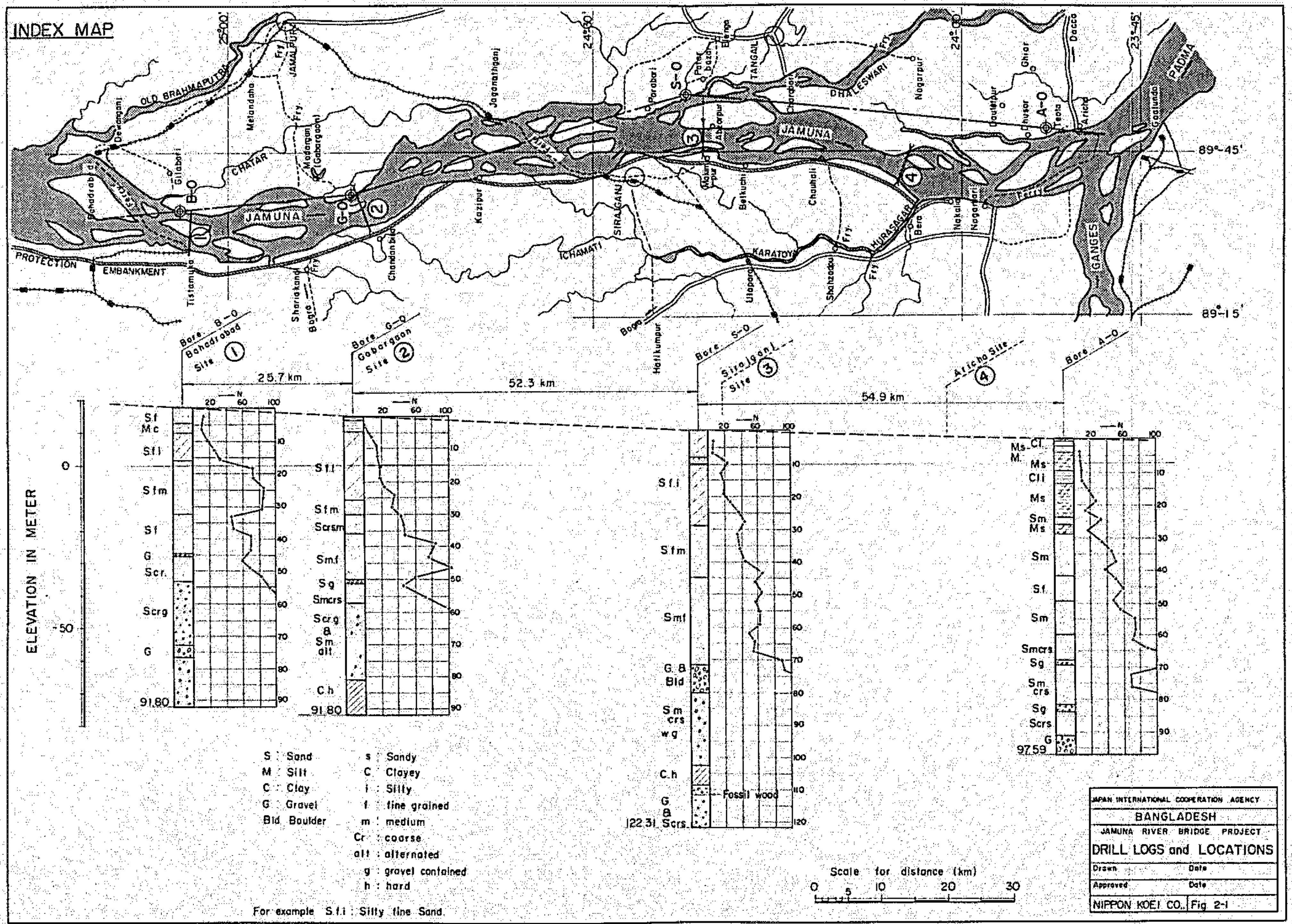
2. Depths are measured from the ground surface of flat land in the vicinity.

3. It is assumed that the gravel bed and soft shale deeper than 70 m (230') are not scoured.

Comparing in the aspects of bearing strength and scouring as shown on the above table, it is noted that the sites 3 and 2 are more favorable than the other two sites. Comparing the sites 3 and 2, the site 3 will be preferable if the gravel bed at 73 m (240') in depth has enough continuing and has resistibility against scouring.

The standard penetration test and lateral load test were also executed using the bore hole. The result of these tests are shown in Chapter III.

The soil samples for physical and mechanical tests were also collected from the bore hole. 132 disturbed samples and 14 undisturbed samples were collected. It is very difficult to collect the undisturbed samples because the soil includes little clay. The results of the tests are shown in Chapter III.


INDEX MAP
JAMUNA
PADMA
GANGES
OLD BRAHMAPUTRA
DHALESWARI
KARATOYA
ICHAMATI
CHATAR
PROTECTION EMBANKMENT
Bore B-O Bahadrabad Site ①
Bore G-O Gobargaon Site ②
Bore S-O Sirajganj Site ③
Aricha Site ④
Bore A-O
25.7 km
52.3 km
54.9 km
ELEVATION IN METER
91.80
91.80
122.31
97.59
Fossil wood
S : Sand
M : Silt
C : Clay
G : Gravel
Bld : Boulder
s : Sandy
C : Clayey
i : Silty
f : fine grained
m : medium
Cr : coarse
alt : alternated
g : gravel contained
h : hard
For example S.f.i : Silty fine Sand.
Scale for distance (km)
JAPAN INTERNATIONAL COOPERATION AGENCY
BANGLADESH
JAMUNA RIVER BRIDGE PROJECT
DRILL LOGS and LOCATIONS
Drawn
Date
Approved
Date
NIPPON KOEI CO.
Fig 2-1

3. Quarry.

The Jamuna River Construction Project includes the problems in its special condition and circumstance.

The Project has required of tremendous amount of rock materials for building of big piers and large scale bank protection for river training. However the greater part of land of Bangladesh is covered with alluvial deposits and young rock formations which can not supply hard rock materials.

Under these special circumstances, possible gravel sources in domestic localities have been throughly surveyed. But, the quarry survey team could not visit to promising sites in the Assam State of India, and the conclusions is not complete yet. Possible quarry sources in the territory of Bangladesh can be divided into three areas.

i. Northeastern border area represented by Bholaganj area,
ii. Northwestern corner district, named Dinajpur-Rangpur, and
iii. Under ground source in the central Rajshahi Division, consist of Pre-tertiary rock formation in the 200 to 500m deep.

(1) Bholaganj area, located at the northern frontier northeast of Sylhet, is overwhelmingly powerful suppliers for gravels. All needs for concrete aggregates during bridge construction can be expected. Its exploitable reserves are estimated at around five million cubic meters. But another millions of cubic meters of boulder material required in the bank protection for river training can not be supplied from the this source.

(2) Northwestern corner districts were also visited at several existing gravel pits. These gravel pits are very small-scale river deposits on piedmont plain. They can not be expected for such big demands as in bridge construction.

(3) At the west of Bogra, the Geological Survey of Bangladesh and Mining Authority have found underground Pre-tertiary rock formations when they were prospecting for limestone and coal mining projects. These projects may be feasible for mining project but big scale daily production such as several thousands cubic meters of boulder from the 200 to 500 m below the surface is not economical. It is judged that the quarry operation is not reliable for its demand of scale and production cost.

Consequently, quarry sources in the Assam State of India has been much expected. But the security condition is not allowed to make reconnaissance survey.

Continuously, the desk study is making for another sources where were newly got information about quarry along the Gages River in the vicinity of West Bengal, India. And the reconnaissance will be carried out in the dry season between November 1974 and March 1975.

According to the comment of Mr. Mesbahuddin Amed, Director General of the Geological Survey of Bangladesh, at the Tokyo Meeting, the source of stone may be expected at the Madhyapara region of the Dinajpur district in the future. Here the Geological Survey of Bangladesh has proved the existence of hard Archaean rock formation at the depth of about 500 ft from the earth surface. If this can be mined, inexhaustible source of supply of excellent concrete aggregates as well as large size blocks of rock would be opened up.

Such stone should be suitable for pitching and should cost be much less than imported one. If the availability of relatively inexpensive stone from this source could be assured, the cost of construction could be considerably reduced. The development of the quarry is not only necessary for this project but also important to the construction in general within the country.

Therefore, we recommend that investigations of the feasibility and cost of extracting this stone on a large scale should be undertaken as soon as possible.

4. River Training Works.

It is the most important problem in the present study to find the most suitable method for river training.

The armoured guide banks and closing dykes were introduced for river training and three types of guide banks were considered at each of the four proposed sites. The armoured guide bank needs a large quantity of pitching stones but this is not available in the land of the People's Republic of Bangladesh at present and its cost would be expensive. Because of the importance of pitching stone, we are investigating the possibility of exploiting sources of low-cost stones.

The length of bridge will be determined in consideration of the minimum width of river at the bridge site. Based on the study of the relationship between flow areas and corresponding river width, we have obtained a value of about 4,000 m (2.5 miles) as the minimum width corresponding to the discharge 90,000 m^3/s (3,178,000 cfs).

Estimation of depth of scouring around bridge piers is another important problem in the present study. If we adopt a well-type substructure, the width or the diameter is supposed to be of the order of 12 m (39'). In this case, the scour depth at piers is estimated to be about 1.8 times as deep as the water depth. On the other hand, if we adopt a multi-column-type substructure, the scour depth will be less than the above. We assumed it to be about 10 m (33') in this case.

5. Bridge Works.

The planning of the Jamuna Bridge must be made on the basis of river training work and it is requested that the total bridge work cost (costs of the both river-training and bridge-construction) must be reduced as much as possible.

For the purpose of river training, the guide-bank system was introduced and three types of guide banks were considered at each of the four proposed sites. The widths between a pair of guide banks which were considered are as follows.

Unit: km (mile)

Site	B-Type	C-Type
Bahadurabad	4.2(2.6)	5.6(3.5)
Gabargaon	4.2(2.6)	5.2(3.2)
Sirajganj	4.2(2.6)	5.6(3.5)
Nagarbari	4.2(2.6)	5.2(3.2)

At each of the proposed sites, type A needs about 5,000 thousands m^3 of pitching stones in order to protect the guide banks and closing dykes from scouring and also deep scouring will be expected around the bridge piers. This means that deep foundations will be requested against scouring and is not economical.

In general, in selecting river width for the bridge, it is most desirable to take a width larger than the present state, or it is undesirable to narrow the present one in view of future possible increase in discharge which will generally take place as river improvement works go forward and considering future river plans as well as future possible change in river bed and other regime. Even if the river width may be narrowed for some reasons, it should be more than about 4000 m.

(1) Width of bridge.

The width of bridge was described in Section (3) of the "SUMMARY AND FUTURE SCHEDULE OF THE STUDY".

(2) Selection of materials.

It is clear that the total length of bridge is determined by the width of waterway between left and right guide banks.

Each clear span of the bridge will be determined by the horizontal clearance of navigation channel which is specified by the BIWTA, that is 250 ft.

Considering the above conditions, steel and concrete (prestressed concrete) are recommended as for the construction materials.

Comparing merits and demerits of both materials, we concluded that steel bridge is more practicable than prestressed concrete bridge in the case of the Jamuna River Bridge.

(3) Superstructure of bridge.

In order to minimize the total cost of bridge construction, it is requested that the structural type of bridge should be selected among various types of bridge applicable to long span.

As is generally known, cantilever truss type and/or continuous truss type is suitable for long span. Therefore, the structural type of main girder and its composition of span are selected as follows taking the minimum horizontal clearance of navigation channel and cost of bridge piers into consideration.

Three equal span continuous truss
(each span length is 100 m (328 ft))
Three equal span continuous truss
(each span length is 150 m (492 ft))
Three equal span cantilever truss
(each span length is 250 m (820 ft))
Three equal span cantilever truss
(each span length is 350 (1148 ft))

Comparing the merits and the demerits of the above-mentioned four types in consideration of cost of construction, we concluded that three span continuous truss (each span length is 492 ft) is more economical than the other cases in the case of the Jamuna Bridge.

(4) Substructure of bridge.

The Jamuna River is a braided river, so even if the guide-bank system is applied to the river training in order to fix the river channel, the deepest part of the river channel will fluctuate to and fro in the river course. Therefore, it is required that the foundation of all piers should have equal depth.

According to the results of our test boring, we found that the reliable layer of thickness 7-10 m (23 - 33 ft) exists at several ten meters below ground level at every proposed site. It seems that such a gravel layer is suitable for the supporting layer of bridge foundation. This means that deep foundation will be needed for every pier of the bridge.

In general, bridge piers should be sunk enough to stand by themselves without any protection around them. In our case, if well foundation is applied, the scour depth at piers is estimated to be as about 1.8 times as the water depth, and if the multi-colums type foundation is applied, the scour depth at piers is assumed at about 10 m. The special consideration was given to the above-mentioned conditions for the design of bridge piers.

Because of the necessity of very deep foundation, well and multi-column types were studied as types of foundation in consideration of simplicity of execution.

From the results of our studies, it has been clarified that the well foundation is more beneficial than the multi-column foundation from the structural and economical point of view.

Therefore, we concluded that the well is suitable for the substructure of the Jamuna Bridge.

6. Railway Access.

The purpose of this study is to find the suitable railway route to connect the bridge with the existing railway line on the both of left and right sides of the Jamuna River. The study was carried out with regard to the four proposed sites. The general description of the route connected with each of the four proposed sites is as follows.

(1) Bahadurabad route.

This route will be about 38 km (23.7 miles) long, diversing from Velurpara Station on the existing Santahar-Bonarpara line (meter gage) on the right side of the Jamuna River, crossing the river and connecting with Durmut Station on the existing Bahadurabad-Jamarpur line (meter gage) on the left side of the river. However, since the proposed link will be a broad gage line, it will be necessary to lay a broad-gage line alongside of the existing meter-gage line for about 62 km (38.8 miles) from Velurpara Station down to Santahar Station which has the main transhipment yard from meter to broad gage.

Furthermore, on the left side of the river, an improvement of the existing line must be considered. The improvement work includes the transition of the existing meter gage line to the broad gage line from Durmut Station to Dacca Station.

Total length of the transition work is about 140 km (88 miles).

(2) Gabargaon route.

This route will diverge from Bogra Station on the right bank, terminating at Jafar Shafee on the existing Jamalpur-Jagannathganj line (mter gage) on the left side, with the total track length of about 55 km (35 miles). In a similar fashion to the Bahadurabad site, it will be necessary to construct a broad gage line alongside of the existing meter gage line for approximately 40 km (25 miles) between Bogra Station and Santahar Station, and also to provide the improvement work in a similar fashion to the Bahadurabad route on the left side of the river. Total length of this improvement work is about 140 km (88 miles).

(3) Sirajganj route.

This route will diverge from Salop Station on the existing Sirajganj branch line (broad gage) on the right bank, crossing the Jamuna River and pass through Tangail on the left bank. This route will run further toward southeast via Mirzapur and Kaliakul connecting with the existing meter gage line in the vicinity of Tungi.

For this plan, it will be necessary to build a main station in Tangail and a transhipment yard from meter gage to broad gage in Azampur to the north of the new airport complex between Dacca and Tungi. The total length of the new line will be 114 km (71 miles).

(4) Nagarbari site.

This route will diverge from Gooakhora Station on the existing Sirajganj branch line (Broad gage) on the right bank, crossing the Jamuna River and other major rivers, Baral, Dhaleswari on the left bank.

In a similar fashion to Sirajganj route, this route will terminate at Azampur Station, the proposed station with a transhipment yard on the Dacca-Tungi line. This route will be the longest among the four with the total length of about 120 km (75 miles).

Elevation of the access railways at every site was determined so as to secure a minimum free-board of three feet above high water level throughout the routes.

7. Highway Access.

The purpose of this study is to find suitable highway accesses to connect the bridge with the all-weather road existing on the both of left and right sides of the Jamuna River.

The study was carried out with regard to the four proposed sites. The following routes were reconnoitered by our team.

Route reconnoitered

Left side of the Jamuna River	Distance (km)
Jamalpur-Bahadurabad	42.0 (26 miles)
Jamalpur-Gabargaon	32.5 (20 ")
Tangail-Gopalganj	26.0 (16 ")
Tangail-Charabari	4.4 (2.7 ")
Tangail-Nagarpur	19.5 (12 ")

Right side of the Jamuna River	Distance (km)
Gobindganj-Shaghatta River bank	21.0 (13 miles)
Bogra-Shariakandi-River bank	21.0 (13 ")
Hatakampur-Sirajganj-River bank	30.8 (19 ")
Sirajganj site	13.8 (8.6 ")
Urapara-River bank	15.0 (9.3 ")

With reference to the results of the study, we propose access highways which connect the bridge with the existing all-weather roads at each of the four proposed sites as follows.

The work was done on the following two types at every proposed site.

Case 1. 2-lane 2-way highway.

Case 2. 4-lane divided highway.

But as mentioned above, it is clarified that the traffic capacity of the Case 1 will cope with even the forecasted traffic volume after fifty years.

Elevation of the access highways at every site was determined so as to secure a minimum free-board of three feet above high water level throughout the whole route.

There are a large number of rivers and canals crossing these access highway routes. We suggest that a considerable portion of the total openings should be closed or narrowed in accordance with detail investigation of drainage.

General scope of highway accesses at each of the four proposed sites is as follows.

	Total length of embankment	Total length of bridge	Total length of spillway crossing
Bahadurabad	64.2km (40.1 miles)	600m (1968')	2700m (8860')
Gabargaon	61.5km (38.4 ")	1000m (3280')	2600m (8530')
Sirajganj	28.6km (17.9 ")	0m (0')	1190m (3900')
Nagarbari	32.6km (20.4 ")	1200m (3940')	1410m (4630')

8. Ferry.

In the People's Republic of Bangladesh, ferries play an important role in road and railway transportation as a substitution of bridges. Therefore, it is necessary to catch the present situation of road and railway ferries in order to study this project.

The study was carried out with respect to the ferries across the Jamuna River and other ferries relating to the access routes.

The ferries are classified as follows;

Bangladesh Railway River Ferry,
BIWTC River Ferry,
R & H Directorate Road Ferry,
District Council Road Ferry, and
Private Road Ferry.

(1) Bangladesh Railway River Ferry.

There are two routes of railway ferries across the Jamuna River.

1) Bahadurabad-Tistamukh route.

The Tistamukh on the right bank and the Bahadurabad on the left bank are both terminals of meter gage. This means that freight wagons may be directly transported across the Jamuna by ferry without the necessity of unloading and reloading the freight at the two terminals.

For this reason, specific freight ferries are operated. The passenger ferry which was temporarily terminated after liberation is now resumed.

2) Sirajganj-Jagannathganj route.

The Sirajganj terminal on the right bank is of broad gage, while the Jagannathganj terminal on the left bank is of meter gage. Consequently, only passenger ferries are operated across the river between the two terminals.

(2) Bangladesh Inland Water Transport Corporation Ferry.

The trunk roads which lead from the capital city of Dacca to the northwest and southwest regions of the People's Republic of Bangladesh are connected by ferries operated from Aricha by the Bangladesh Inland Water Transport Corporation, as the Jamuna River and Padma River route ferries.

1) Jamuna River route.
   a. Aricha-Nagarbari route.

2) Padma River route.
   a. Aricha-Goarundo route.
   b. Aricha-Tepurakandi route.

The Jamuna River route connects the Nagarbari-Bogra trunk road on the right bank of the river with the capital city of Dacca and is the crossing for the domestic transportation route with the Rajahi Division in the northwest of the People's Republic of Bangladesh.

The Padma River route connects the Faridpur-Jessore trunk road of the southwestern Khulna Division on the right bank of the river with the capital city of Dacca. This trunk road is the only land transportation route between Dacca and the other major parts of the People's Republic of Bangladesh and also the transportation route with India.

(3) Road and Highway Directrate Road Ferry.

In August 1973, there were about 40 ferry crossings of various scales for the national highway net work under the control of the Road and Highway Directrate.

There are no official gradings for these crossings, but they may be graded into three classes in accordance with their importance.

Class 1
These are the crossings for the main trunk road, and are of the heaviest traffic volume and traffic density.

Class 2
These are the crossings for other trunk roads, where the traffic density is lower although traffic remains heavy.

Class 3

These are the crossings of lesser importance for the subsidiary roads.

(4) Private Party Ferry.

The ferry crossings on the local roads are operated on a small scale by private parties and the objective is no more than serving bullock cart and pedestrian traffic.

The points of ferry operation on the east bank of the Jamuna River are limited to the Dhaleswari River and Chatal River, while those on the west bank are the Karatoa River, the Bangali River and the Katakari River, all of these being medium size rivers. Ferries are operated during the rainy season across the unknown small rivers, but during the dry season, these small rivers can either be forded or are completely dried up.

9. Evaluation of Traffic.

(1) General.

The purpose of this study is to provide data and information to assess the economic feasibility for the Jamuna River Construction Project, by making a comprehensive survey concerning the current status of the regional economy which generates traffic and the present transportation demands and by forecasting the future development of the regional economy and the traffic demand.

(2) Estimated passenger trips crossing the Jamuna.

According to the results of the studies, in view of passenger trips by mode, the largest passenger trips are estimated to pass through the bridge annually at the Nagarbari site and the Sirajganj site and the Bahadurabad and/or the Gabargaon site closely comes next up to 2022/23. (See Table 2-1)

Table 2-1 Estimated Passenger Trips Crossing the Jamuna

Unit: 10,000 persons/year

Site/Mode \ Year	1982/83	1992/93	2002/03	2012/13	2022/23
Bahadurabad, Gabargaon					
Overland	1,484.5	2,326.0	3,424.1	3,715.1	4,006.1
Waterborne	507.3	809.0	900.0	900.0	900.0
Total	1,991.8	3,135.0	4,324.1	4,615.1	4,906.1
Sirajganj					
Overland	1,613.0	2,528.0	3,452.4	3,732.4	4,012.4
Waterborne	563.8	896.0	1,000.0	1,000.0	1,000.0
Total	2,176.8	3,424.0	4,452.4	4,732.4	5,012.4
Nagarbari					
Overland	1,743.2	2,691.0	3,856.8	4,165.3	4,473.8
Waterborne	734.7	1,199.0	1,200.0	1,200.0	1,200.0
Total	2,477.9	3,890.0	5,056.8	5,365.0	5,637.8

(3) Estimated commodity flow crossing the Jamuna.

Based upon the study of the commodity flow crossing the Jamuna, the largest commodity flow is estimated to pass through the bridge annually at the Nagarbari site, the Sirajganj site closely comes next and Bahadurabad and/or the Gabargaon site falls behind any of the others up to 2022/23.

Table 2-2 Estimated Commodity Flow Crossing the Jamuna

Unit: 1,000 tons/year

Site/Mode \ Year	1982/83	1992/93	2002/03	2012/13	2022/23
Bahadurabad, Gabargaon					
Overland	860 (1,718)	1,365 (2,793)	2,167 (4,541)	3,440 (7,383)	4,359 (9,338)
Waterborne	165	275	275	275	275
Total	1,025 (1,883)	1,640 (3,068)	2,892 (4,816)	3,715 (7,658)	4,634 (9,613)
Sirajganj					
Overland	1,198 (1,931)	1,902 (3,139)	3,019 (5,104)	4,793 (8,298)	6,465 (11,251)
Waterborne	184	310	310	310	310
Total	1,382 (2,115)	2,212 (3,449)	3,329 (5,414)	5,103 (8,608)	6,775 (11,561)
Nagarbari					
Overland	1,320 (2,017)	2,096 (3,279)	3,327 (5,331)	5,281 (8,668)	6,640 (11,067)
Waterborne	174	285	285	285	285
Total	1,494 (2,191)	2,381 (3,564)	3,612 (5,616)	5,566 (8,953)	6,925 (11,352)

Note : Figure in ( ) shows the goods movement in the presence of development projects in Rajshahi Division.

10. Evaluation of the Four Proposed Sites.

(1) Stability of the river channel.

Stability of the river channel was studied in view of the geomorphology and river-morphology.

From the geomorphological point of view, the Sirajganj narrow is most suitable among the four, the Gabargaon site comes closely next, the Bahadurabad site compares unfavorably with the former two and the Nagarbari site falls behind any of the others.

From the river-morphological point of view, the Nagarbari site is the worst one while the other three are almost equal judging from the fact that the variation of the river bank lines is almost constant since nearly 1860, but from the aspect of the size of river width, the Gabargaon site is best and the Bahadurabad site and the Sirajganj site are almost equal.

Therefore, from both the geomorphological and the river-morphologicial points of view, there is nothing to choose between the two sites, Sirajganj and Gabargaon.

(2) Traffic volume to be expected in the future.

As shown in Section 9 of this Chapter, the passengers and goods across the Jamuna River at each of the four proposed sites are estimated with regard to the period from 1982/83 to 2022/23.

As for the goods movement across the Jamuna river (see Table 2-2), we can expect the same tendency as mentioned above. In the case of the Nagarbari or the Sirajganj site, some diversion from inlandwater transport cargo moving between Khluna and Dacca was taken into consideration.

On the basis of the above-mentioned results, the Sirajganj site or the Nagarbari site is more preferable than the Gabargaon site or the Bahadurabad site for the bridge crossing in view of the future overland-transport system of the People's Republic of Bangladesh.

(3) Cost of construction.

The total bridge-work cost (cost of the both works of river-training and bridge construction) is one of the most important elements to determine the most suitable site of the bridge.

The total length of bridge will be determined in consideration of the width between a pair of guide banks. Three types of guide banks were considered at each of the proposed sites. These are Type-A, Type-B and Type-C. Type-A of guide banks was provided with a channel width of 2,000 m (1.25 miles), Type-B was provided with a channel width of about 4,000 m (2.5 miles) and Type-C was provided with a channel width of about 5,500 m (3.4 miles).

Type-A is undesirable from the results of study. Therefore, in the present planning of the bridge, Type-B (total length of bridge is 4,200 m) and Type-C (total length of bridge is 5,200 m or 5,600 m) were considered. Accordingly, much change in cost of construction of bridge will not be expected for each case respectively. In such cases, major element relating to the cost of bridge is the cost of transportation of construction materials, construction machinery and others.

The cost of transportation changes corresponding to the distance and method of transportation, but major part of imported goods will be transported from Chittagong or Khluna to the bridge site by the inland water transport, therefore the downstream bridge site is more economical than the upstream one from the viewpoint of transportation cost. The rough estimation of the cost of construction for each of the four proposed sites is shown in Table 2-3.

Table 2-3 Rough Estimation of Construction Costs of Jamuna River Bridge

River training : Guide bank system.

Bridge : 3-span continuous steel truss (3 @ 150 m), well foundations and approaches (highway : 2 lanes, railway : single broad gage).

Access railway : Broad gage (5'6"), single track.

Access highway : 2 lanes (24').

Unit : 10 crore TK

Proposed Site for Bridge Construction	Distance between Guide Banks Km (mile)	Bridge			Access			Grand Total
		River Training	Bridge	Total	Railway	Highway	Total	
Bahadurabad	4.2 (2.6)	8.3	22.3	30.5	12.9	2.3	15.2	46
	5.6 (3.5)	6.9	27.9	34.7	12.9	2.3	15.2	50
Gabargaon	4.2 (2.6)	9.6	22.3	31.9	13.0	2.6	15.6	48
	5.2 (3.3)	7.9	26.3	34.2	13.0	2.6	15.6	50
Sirajganj	4.2 (2.6)	9.3	22.3	31.6	8.9	2.8	11.7	43
	5.6 (3.5)	8.0	28.0	36.0	8.9	2.8	11.7	48
Nagarbari	4.2 (2.6)	11.3	23.9	35.2	10.3	1.6	11.9	47
	5.2 (3.3)	9.3	27.6	36.9	10.3	1.6	11.9	49

Note :

1. All costs given in the above table were counted at unit prices as of March 1974.
2. The following costs are excluded from the grand total of the above table and will roughly amount to TK 2,200,000,000.
   a. Costs for administration and engineering.
   b. Costs of general facilities for construction.
   c. Contingencies.
3. The project cost will roughly amount to TK 6,700,000,000 to TK 7,000,000,000 adding the above cost.
4. Costs of Sirajganj are based on closing the upper one of the offtakes of the Dhaleswari River.

As shown in Table 2-3, as for the total cost of construction of bridge, we can not find much difference among the four proposed sites. But there are some difference of the grand total cost among the four proposed sites owing to their circumstances.

According to the above-mentioned assesments, the priority order of the four proposed sites was evaluated and results of the evaluation are shown as Table 2-4. The results are expressed in order of A,A', B and C. A has top most evaluation.

Now, we wish to propose the Sirajganj site as the most suitable one for the Jamuna River crossing. The Dhaleswari crossing for this site is included in the railway and highway accesses. The study of this crossing is also taken into consideration.

According to the results of the discussion at the Dacca Meeting, the treatment of the Dhaleswari River was determined as follows. (See "Agreed Minutes at Dacca Meeting for Jamuna Bridge Project, Bangladesh")

a. The upper inlet channel of the Dhaleswari River shall be closed by the access road and the lower inlet channel shall be so improved as to have the same function as both the upper one and lower one combined.

b. The improved lower channel will require maintenance. Cost for the maintenance shall be included in the cost in the B/C (benefit-cost) analysis of the project.

Figure of passengers means the estimated number of passenger trips crossing the Jamuna River by train or by car at 2022/23 assuming the bridge to be opened to traffic before 2022/23 (see Table 2-1). Figure of goods means the estimated tonnage of goods across the Jamuna River by train or by truck at 2022/23 assuming a bridge to be opened before 2022 (see Table 2-2).

Table 2-4 Evaluation of the proposed sites

Proposed Sites	Stability of River		Cost of Construction				Grand Total		Traffic Volume		Evaluation of Priority
	Geomor-phology	River-morphology	River Works and Bridge Works		Railway and Highway Access		River Width		Passenger Trips	Commodity Flow	
			River Width		Railway	Highway	4.2km	5.2-5.6km			
			4.2km	5.2-5.6km							
BAHADURABAD	B	A'	30.5	34.7	12.9	2.3	46	50	4906.1	4634 (9613)	B
GABARGAON	A'	A	31.9	34.2	13.0	2.6	48	50	4906.1	4634 (9613)	A'
SIRAJGANJ	A	A'	31.6	36.0	8.9	2.8	43	48	5012.4	6775 (11561)	A
NAGARBARI	C	C	35.2	36.9	10.3	1.6	47	49	5637.8	6925 (11352)	B

Note:
1. Unit
   - Unit of cost: 10 crore Taka
   - Unit of passenger trips: 10,000 persons/year
   - Unit of commodity flow: 1,000 tons/year
2. Figure of passenger trips shows the estimated passenger trips crossing the Jamuna in 2022/23.
3. Figure of commodity flow shows the estimated commodity flow crossing the Jamuna in 2022/23.
   Figure in (   ) shows the goods movement in the presence of development projects in Rajshahi Division.

CHAPTER III

GEOLOGICAL AND QUARRY STUDY

1. Introduction.

The Jamuna River Bridge Construction Project includes characteristic geological problems in its special condition and circumstance. One is subsurface conditions of the projected sites where deep foundations of bridge piers are required, because the river flows over thick alluvial plain where no basal rock is exposed. Another problem is an availability of tremendous amount of construction materials especially for rock material which is required not only to build big piers and abutments but also to build large scale bank protection for river training. Greater parts of the land of Bangladesh are covered with alluvial and geologically young rock formations which cannot supply hard rock materials.

Under these special circumstances, the geological study has been planned in two categories. These are subsurface geological studies at the proposed bridge sites and geological reconnaissance studies on possible quarry sites for rock materials.

2. General Purpose and Features of the Study Works.

Geological studies at the first stage of the Jamuna Bridge Construction Project are to find out general features of subsurface soil conditions at four proposed bridge sites on the one hand and to find out availability of favourable quarry sites which can supply enough rock materials required in the construction on the other hand.

Bridge construction scheme on the Jamuna has long been taken under consideration in this country. The following four desirable locations have been proposed in wide range of 150 km along middle reaches of the Jamuna -- from Bahadrabad down to Nagarbari.

Four Proposed Bridge Sites

Bridge site	Location	Test drill hole (depth)
1. Bahadrabad site	Uppermost site, South of ferry site of the State Railway	B-0 (91.8m)
2. Gobargaon site	West of Jamalpur Town	G-0 (91.8m)
3. Sirajganj site	South of Sirajganj Town	S-0 (122.3m)
4. Aricha site (Nagarbari)	North of crossing of Dacca-Ishurdi Highway on the Jamuna River	A-0 (97.6m)

Total length of the drillings: (92m-120m) x 4 holes: 403.5m(1320')

Standard penetration tests at every 3.05m(10') ....132 tests

Lateral load tests (LLT) .... 20 tests

Soil mechanical tests in laboratory

for undisturbed samples .... 14 samples

for disturbed samples ....132 samples

Our first-stage work is to study general properties of alluvial soil at each site by drill samples and their soil mechanical characteristics --- one drill hole at each site. The purpose of the study is to obtain sequence of alluvial depositions, especially on their soil mechanical properties which would attribute soundness of the pier foundation during the after bridge construction. One drill hole at each site is, of course, not sufficient to correlate the four bridge sites, even though one drill log represents several square kilometers in such a big scale alluvial deposits basin. The four drill logs obtained are tentatively shown in the attached drawing Fig. 2-1 to show general tendency of serial deposits of alluvial layers.

The land of Bangladesh is mostly occupied by the Tertiary and Quaternary formations and is characteristic for its scarcity of rock materials in the land. Under consideration of a bridge project over the gigantic Jamuna River, requirements of pitching stone to be used against erosion would be the order of several million cubic meters --- more than one hundred million cu. ft. ---. They will be used in several years during and after construction; that is : 3,000 - 4,000 cu. meter per day or 100,000 cu. ft. per day of rock supply is needed. Beside of the pitching stone, there would be requested several hundred thousand cubic meters of concrete aggregates for building bridge piers.

A few examples of gravel quarries are reported which are working river gravel transported from Indian territories and deposited in Bangladesh riverbed. Possible supply sources for the bridge construction have been suggested by the Preliminary Survey Report within the territory and in the neighboring Assam State of India. These sources are as follows.

<u>Probable Sources of Rock Material</u>

Bangladesh Territory

Sylhet region in Northeast

Rangpur region in Northwest

Vicinity of Bogra Town

Indian Territory

Baghmara, southern frontier of Assam State

West of Tura Town, Assam State

Dhubri region along the Jamuna, Assam State

All the localities in Bangladesh territory were visited and surveyed. Those in the northern and western Bangladesh are all small-scaled river deposits on the piedmont plain, and cannot be expected for such a big demand as the bridge construction. Bholaganj gravel in the Sylhet District is the only exception. It can be a promising producer of big amount of gravels.

While, scheduled reconnaissance trips in Assam State were refused by the Indian Government for reasons of security conditions. Then, provision of useful information about these promising quarries were asked to the government of India. No reply has been received yet at the time of presentation of this report.

Members engaged in the Geological Survey

M. Sakaita: Team Leader, Engineering Geologist
7, Jan. - 6, Feb.; 28, Feb. - 14, Mar.

M. Chida : Soil Survey, Engineering Geologist
7, Jan. - 29, Mar.

Y. Ito : Soil Survey, Engineering Geologist
7, Jan. - 29, Mar.

Y. Yoshida: Quarry Survey, Geologist 7, Jan. - 23, Feb.

M. Oyama : Quarry Survey, Mining Engineer
7, Jan. - 23, Feb.

Counterpart Geologist, Mr. Kamuldin from Bangladesh Geological Survey, accompanied and cooperated with the above.

Equipment used at Field Work

L-38 Longyear Rotary Drilling Machine

Joy Hand-feed Rotary Drilling Machine

Lateral Load Tester (LLT)

Soil Mechanical Tests in Soil Laboratory of Soiltech Co., Dacca.

3. Summary of the Surveys and Tests with Their Conclusions in the Subsurface Condition of the Bridge Site.

Geological studies are divided into two parts, one is subsurface geological study around the bridge sites by means of test drillings and accompanying soil mechanical tests. The other is geological reconnaissance of quarry sites for rock materials. Summary and conclusions will be stated separately.

(1) Subsurface geological study.

Each one boring point was selected at four proposed bridge sites, as shown on the attached paper. The following mechanical tests in situ and laboratory tests were performed during drilling work.

i) Standard Penetration Tests at every 10' depth interval in each hole.

ii) Several times of Lateral Load Tests in each drill hole.

iii) Physical and mechanical Tests on the sample taken at drill holes as follows.

	Disturbed Samples (for physical test)	Undisturbed Samples (for mechanical test)
A-0	32	6
S-0	40	4
G-0	30	2
B-0	30	2
Total	132	14

As the alluvial sequence is mostly sandy, partly intercalating sand and gravel with little clayey material, it was very difficult to keep undisturbed sample in the sampler tube. Only 14 samples were taken in undisturbed form. Disturbed samples were taken at every standard penetration test as many as possible. Drill points and their results are shown in the drawing Fig. 2-1.

These four drilling points are located at distance of 25 km - 55 km apart. Nevertheless, extensive Jamuna Alluvium may be deposited in large scale and supposed to be rather simple and continuous sedimental sequence. Each of the four drill logs can be represent typical sequence of deposits around each bridge site.

(2) Comparison of the four proposed bridge sites.

From engineering point of view, the subsurface geological study has been directed on two major points; location of reliable bed or formation enough to support heavy pier foundation and the bed enough resistive against scoring caused by eddy current around pier body after construction.

Considering many engineering factors such as shape, number and interval of piers, and hydrological agents under flood condition, it is assumed that the supporting bed should have N-value of more than 100 and location of below 70 m from ground surface.

According to the above criteria comparison is summarized as in the following table.

Table: Summarization of Supporting Bed at Each Site

	Compacted layer having N-value 100	Sufficiently compacted layer against scoring
Site 1	below 55mm from surface	92m from surface
Site 2	60m	81m (mudstone)
Site 3	73m	73m (gravel)
Site 4	85m	85m (gravel)

From the view point of soundness against supporting the piers, Site-2 and Site-3 are more preferable than the other sites. If the gravel layer at the depth of 73 m at Site-3 is well continued horizontally, Site-3 is most preferable. But if the gravel layer is distributed discontinuously the mudstone in Site-2 is most reliable and Site-2 is most favourable in spite of its deeper location --- 81 m below the ground surface.

4. Quarry Study for Rock Materials.

As stated before, possible gravel sources in domestic localities have been thoroughly surveyed. But several promising quarry sites in the Assam State of India, which can be expected large scale supply, could not be visited and the conclusions are incomplete.

(1) Domestic sources.

Possible quarry source in the territory of Bangladesh can be classified in three.

i. Northeastern border area represented by Bholaganj area.

ii. Northwestern corner district; Dinajpur-Rangpur.

iii. Pre-tertiary rock formation 200 - 500m underground in the central Rajshahi District.

These three possible areas were reconnoitered in January and February 1974.

i) Bholaganj area, located at northern frontier, northeast of Sylhet is the overwhelmingly powerful suppliers for gravels. All needs for concrete aggregates during bridge construction can be expected to be supplied from the Bholaganj area. Its exploitation reserve is estimated at around 5 million m^3. But another millions of cubic meters of boulder material required in bank protection for river training cannot be supplied from this source.

ii) Northwestern corner district were also visited at several existing gravel pits. These gravel pits are all small-scale river deposits on the piedmont plain. These deposits are ill-sorted. There are small gravels scattered and embedded in sand layer. Gravel percentage in the said layer is several percents. They cannot be expected for such a big demand as in bridge construction.

iii) In the west of Bogra, the Geological Survey of Bangladesh and mining authority have found the underground Pre-tertiary rock formations. Subsurface geology have been well clarified. Limestone and coal reserve are confirmed and exploitation of these materials is now under planning. Preparating works will be started soon. Important preparation is deep shaft-sinkings which dig through alluvial and Tertiary formation coverings of 200-500m in thickness. It will need at least two years preparation and big initial investments including power supply. Although project may be feasible for limestone and coal production, it is not economical that there happens big scale daily production like several thousand cubic meters of boulder from underground. It is judged that the quarry operation is not reliable for its demand scale and production cost.

Mahyapara area of Dinajpur District is recently recommended as new promising quarry site by the Geological Survey of Bangladesh. The area is now under investigation by the Bangladesh Mineral Exploration and Development. Study of the area is scheduled in the second stage of field survey in coming December, 1974.

(2) Quarry source in India.

It has been much expected that reliable quarry source can be found in the Assam State in India. But the security condition did not allow to make reconnaissance survey. Repeated negotiation with the Indian authority could not solve the conditions.

After serial desk studies and information available, another possible source along the Ganges River, West Bengal has been suggested. New reconnaissance plan in the Ganges area is now under planning for the second year survey program in November-December, 1974.

Under such circumstances the conclusion of the quarry study is postponed to the second-stage field reconnaissance.

Production and transportation of rock material are another problem. Initial big investment will be required not only for construction of quarry facilities but for preparation of supplementary railway capacity and conveyable system on the river. They have to be included in the future study items at the second stage.

Table 3-1 Summary of Grain Size, Density and N-Value

A — O

Horizon	N Value	DIN C	DIN M	DIN S F	DIN S M	DIN S C	DIN G	JIS C	JIS M	JIS S F	JIS S C	JIS G	D_{10} (mm)	D_{60} (mm)	U_c	r_s	w	r_t
Au2	14	5	68	28	3			8	69	24			002	0064	5.42	270	3623	(1.91)
Au1	46		11	41	44				14	80	11		0052	023	404	270	2649	1.99
Am3	87		8	18	65	8			13	54	36		0.101	039	5.41	270	1969	2.11
Am2																		
Am1																		
Aℓ3~Aℓ2	167		10	16	56	21	12		12	51	30	12	0063	046	736	270	1455	222
Aℓ			6	14	13	12	62		5	21	17	57	0168	11.65	5941		11.19	
Du2																		
Dℓ2																		
Dℓ1																		

S — O

Horizon	N Value	DIN C	DIN M	DIN S F	DIN S M	DIN S C	DIN G	JIS C	JIS M	JIS S F	JIS S C	JIS G	D_{10} (mm)	D_{60} (mm)	U_c	r_s	w	r_t
Au2	21		10	42	46	4			13	82	9		0079	0265	364	270	2782	(183)
Au1	45		10	29	60				15	76	10		0.067	026	493	270	2602	(180)
Am3	61		9	21	75				11	67	23		0.069	035	5.66	270	1979	2.11
Am2																		
Am1																		
Aℓ3~Aℓ2																		
Aℓ			3	7	18	11	59		5	19	16	59	024	9.00	3560	2.65	1054	229
Du2			23	21	48	10	2		26	55	18	2	0021	031	1498	269	17.69	2.15
Dℓ2		3	52	26	19			3	59	38			0009	0078	832	269	2170	207
Dℓ1			10	19	39	16	16		12	44	26	16	0067	1.19	1683	269	1560	2.19

G — O

Horizon	N Value	DIN C	DIN M	DIN S F	DIN S M	DIN S C	DIN G	JIS C	JIS M	JIS S F	JIS S C	JIS G	D_{10} (mm)	D_{60} (mm)	U_c	r_s	w	r_t
Au2	17	10	23	33	42			20	26	70	7		0051	0201	452	271	2536	(187)
Au1																		
Am3	41		7	38	54	1			9	75	16		0088	031	3.54	2.71	2380	203
Am2	78		13	30	55	4			16	74	17		0053	028	632	271	2270	2.06
Am1																		
Aℓ3~Aℓ2	58		9	9	60	12			11	66	23		0068	033	5.03	271	2020	2.11
Aℓ1																		
Du2			15	30	49	10	5		19	60	29	5	0.046	0.29	795	271	17.90	215
Dℓ2		9	80	10	3	2		17	77	6	3		00025	0027	11.18	2.70	1950	211

B — O

Horizon	N Value	DIN C	DIN M	DIN S F	DIN S M	DIN S C	DIN G	JIS C	JIS M	JIS S F	JIS S C	JIS G	D_{10} (mm)	D_{60} (mm)	U_c	r_s	w	r_t
Au2	18		22	40	36			3	24	74			0054	0.17	359	270	2439	(193)
Au1																		
Am3																		
Am2	72		16	52	47			2	21	80			0042	0.21	5.80	270	2317	205
Am1	57		17	46	37				20	80			0032	0.21	709	270	2440	202
Aℓ3~Aℓ2	70		10	16	73	1			11	56	33		0.07	0.40	698	2.70	1833	214
Aℓ1																		
Du2			7	11	54	19	11		6	44	38	11	0145	1.17	758	2.71	1930	2.11
Dℓ2																		

Uniformity Coeficient $U_c = D_{60}/D_{10}$; Estimated Wet Density (r_t)

CHART 3-1 **SUMMARIZED CHART OF SOIL CHARACTER**

PROJECT JAMUNA BRIDGE (SIRAJGANJ SITE) HOLE NO. S - 0 EL. APROX. 10.7 m GWL. GL. - 2.70 m COORDINATE: N 24°-22'-25" E 89°-50'-10"

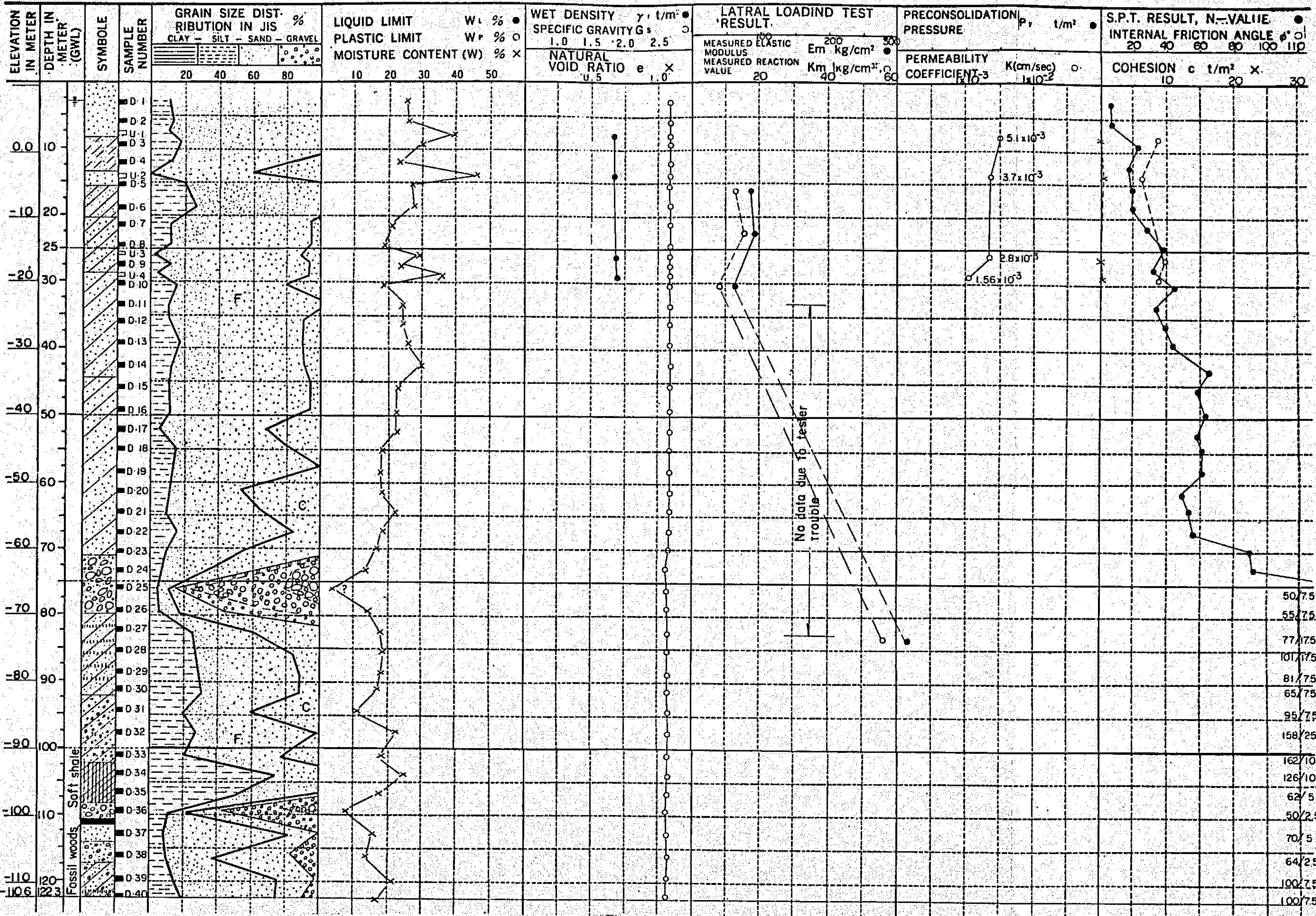


CHART 3-2 **SUMMARIZED CHART OF SOIL CHARACTER**

PROJECT JAMUNA BRIDGE (ARICHA) HOLE NO. A - 0 EL. APROX. 7.3 m GWL. GL. - 1.42 m COORDINATE: N. 23°-52'-57" E 89°-46'-45"

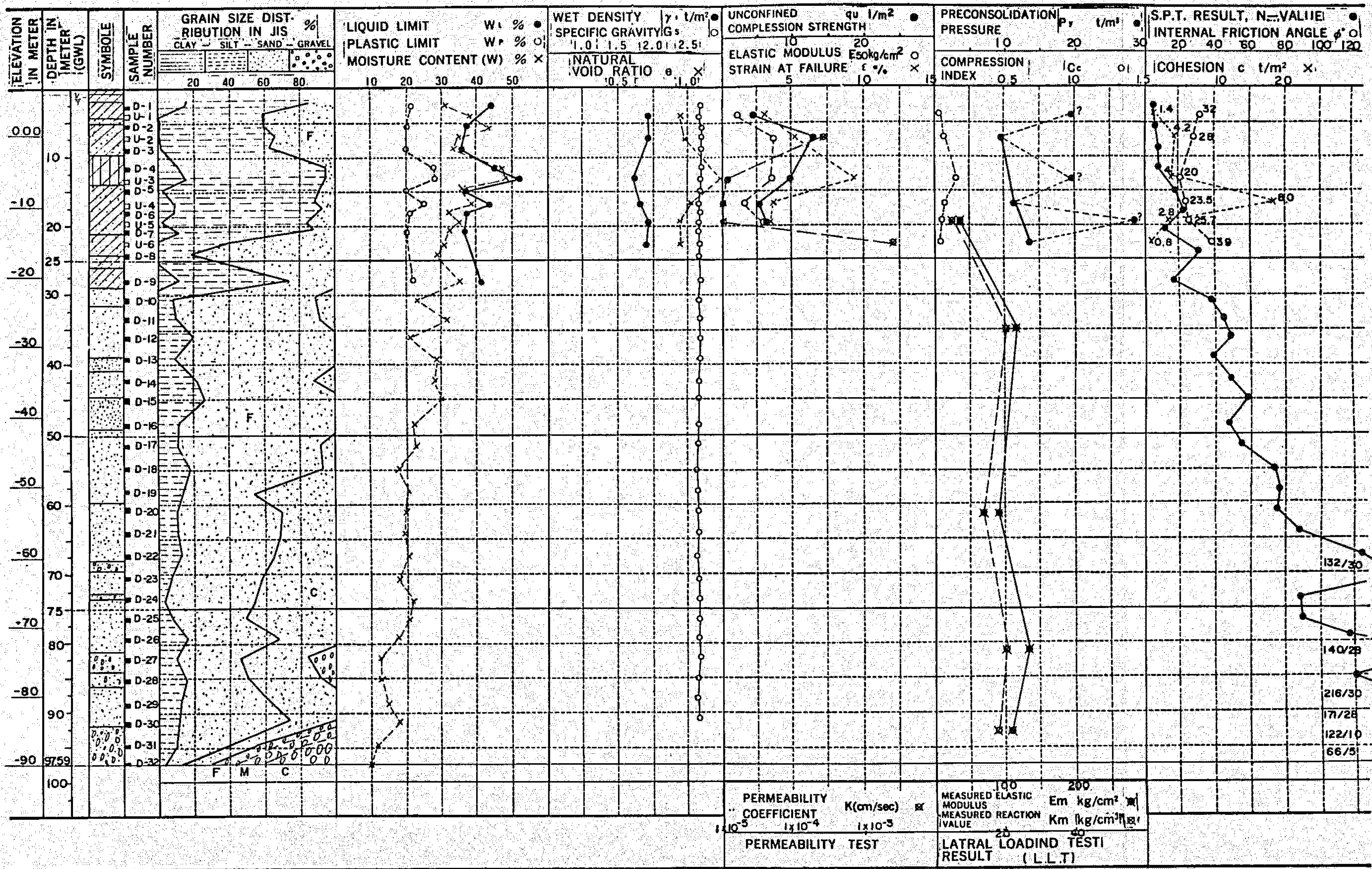


CHART 3-3 **SUMMARIZED CHART OF SOIL CHARACTER**

PROJECT: JAMUNA BRIDGE (GABARGAON) HOLE NO. G – 0 EL. APROX. 15.0 m GWL. GL. – 3.20 m COORDINATE: N. 24°-50'-05" E. 89°-41'-05"

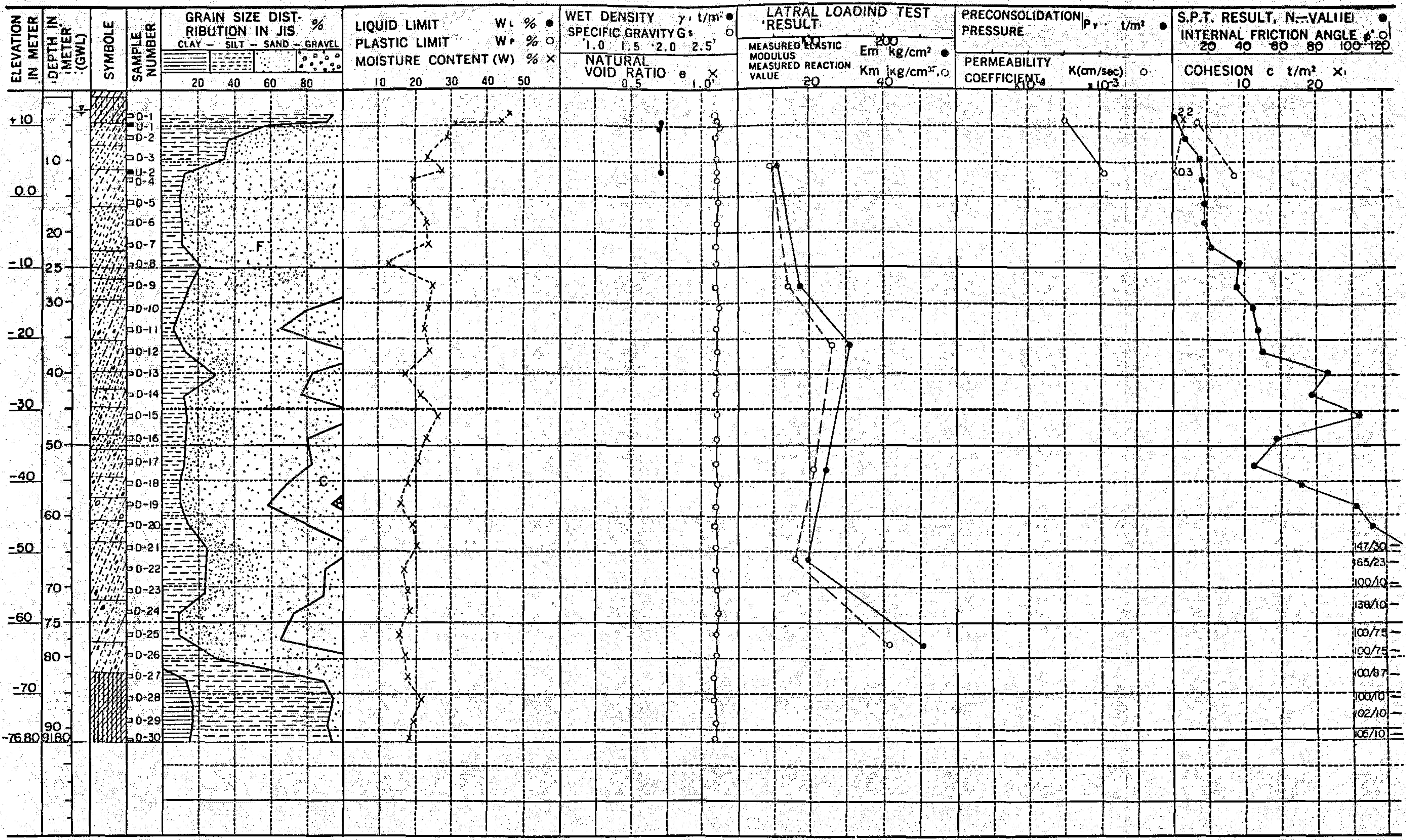
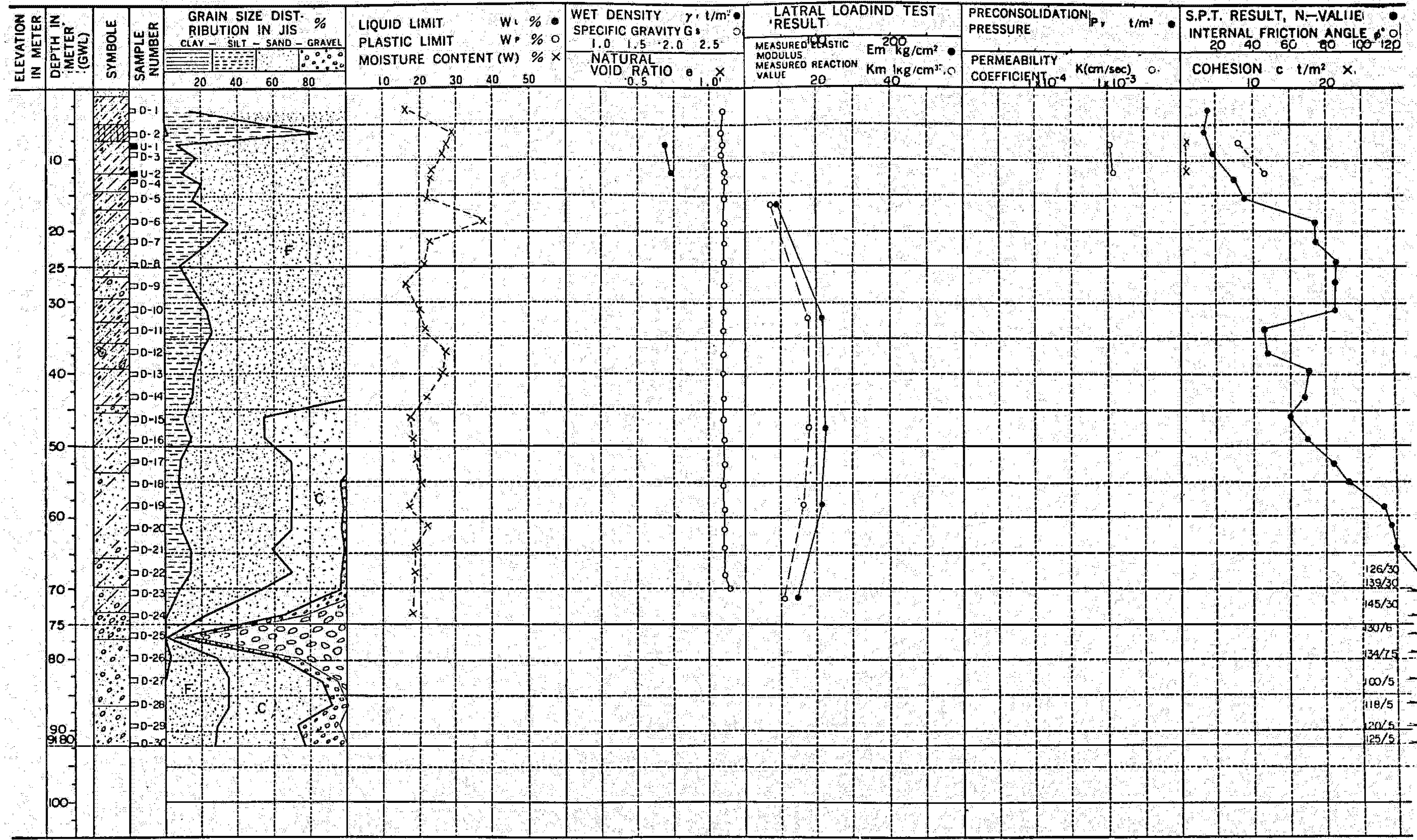


CHART 3-4 **SUMMARIZED CHART OF SOIL CHARACTER**

PROJECT: JAMUNA BRIDGE (BAHADRABAD) HOLE NO. B – 0 EL. APROX. 17.5 m GWL. GL. – 3.50 m COORDINATE: N. 25°-04'-20" E 89°-40'-05"



CHAPTER IV

STUDY OF RIVER TRAINING WORKS

1. Scope of Works of this Study.

The Japan International Cooperation Agency (the former OTCA, Japan) sent a prefeasibility study team to the People's Republic of Bangladesh at her request to make a preliminary study of the feasibility of the Jamuna Bridge Project. The team, after about one month's stay in Bangladesh from November to December in 1972, reported to the OTCA (1) that they picked out four sites on the river as proposed ones for spanning, namely, from upstream to downstream, downstream of Bahadurabad, near Gabargaon, about 10 km downstream of Sirajganj and about 20 km upstream of Aricha, (2) that the most suitable site should be chosen from among the above four sites and (3) that it would take three years to finish the feasibility study and in the first half of the study period the selection of the most suitable site should be done and in the latter half of the period the feasibility study should be made with regard to the site selected. In August 1973, the Inception Report was submitted by the JICA to the Bangladesh Government naturally on the basis of the conclusion of the Prefeasibility Study Team.

In the Inception Report, three criteria have been mentioned for selection of the most suitable site, namely (1) stability of river channel, (2) traffic volume to be expected in the future and (3) costs of construction. Naturally, this report deals with the scope of works for the first stage of the study, namely the comparison of the stability of river channels at the four proposed sites and the rough estimation of construction costs of river training works intending to present one element for comparison of the total costs of construction with respect to the four sites. For this purpose, three types of guide banks or three types of river training works were considered for each site and the costs of the training works were roughly estimated in compliance with the accuracy required for comparison.

2. Natural Features of the River.

The Brahmaputra River takes its rise in Lake Monosarwar which is located in the northern part of the Himalaya Mountains, running through the Tibetan Plateau from west to east, traversing the Himalayas in the eastern part and running through the Assam Plain from east to west, turns to the south in the west of the Shillong Plateau. After that, passing through the national border, enters into Bangladesh and, joining the Tista River, running almost straight to the south, joins with the Ganges River near Aricha. The river is called the Brahmaputra-Jamuna in its part from the northern border to the confluence with the Ganges. After the joining, changing its name to the Padma, the river goes down to the southeast about 100 km and after joining the Meghna River near the town of Chandpur, pours into the Bay of Bengal. The drainage area stretches over the three countries of China, India and Bangladesh. This river is one of the largest in the world.

On the other hand, the Ganges River originates in the glacier of Mt. Gangotori (6,614 m), runs through the Hindustan Plain from west to east and turns to the southeast at the edge of the Rajmahal Hill and then, flowing down in the Ganges Plain, joins with the Brahmaputra-Jamuna River at Aricha.

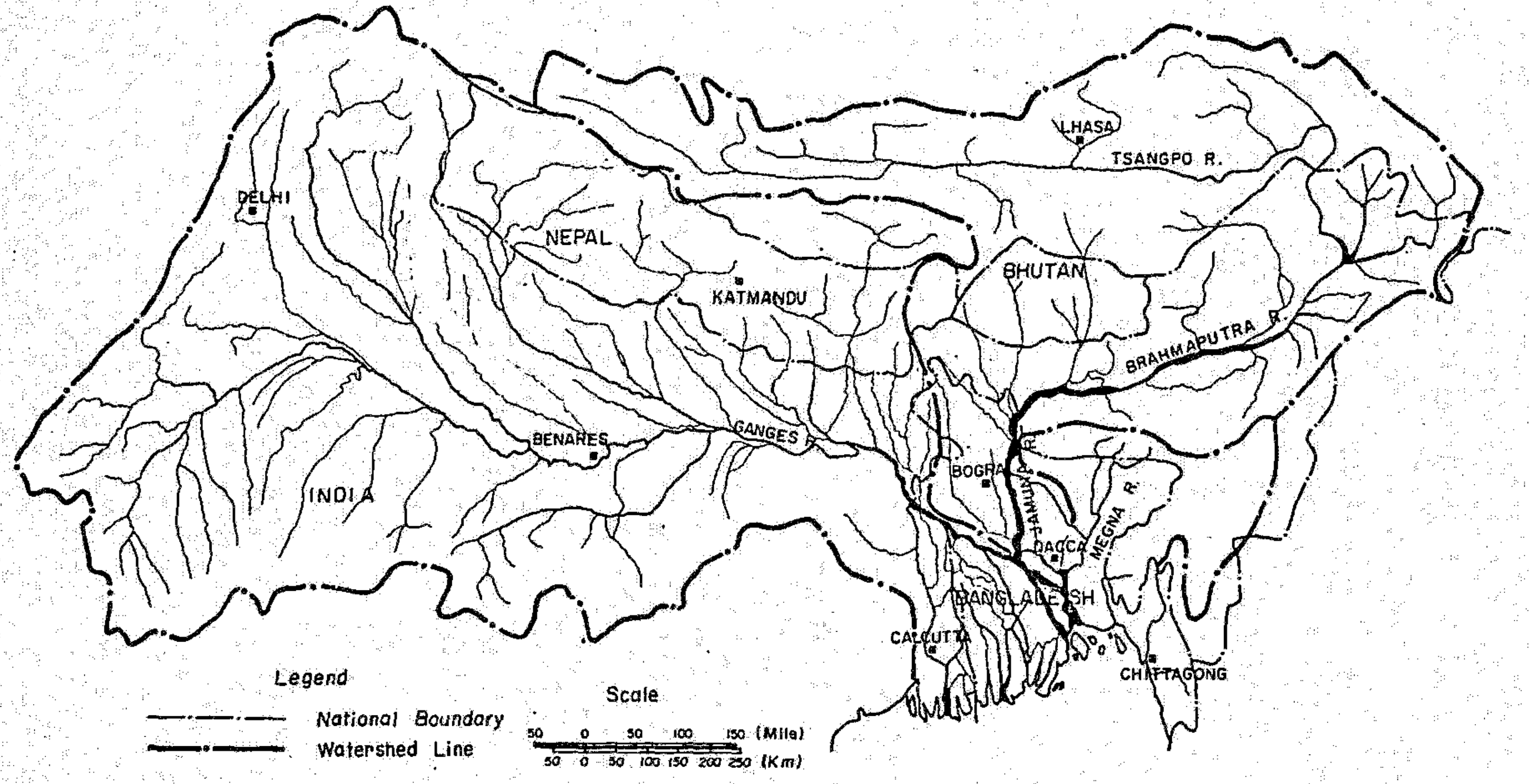
The catchment area and the length of the Brahmaputra-Jamuna River at the confluence with the Ganges are 580,000 km^2 and 2,600 km while those of the Ganges at the confluence are 977,000 km^2 and 2,200 km.

The meteorology in Bangladesh belongs to so-called the tropical and there is a clear distinction of two seasons, the dry and the wet. According to the records at the Sirajganj Meteorolonical Station, the minimum of monthly mean temperature appears in January at about 18°C and the maximum occurs in April or May at about 29°C. The lowest and the highest in the past are 7.2°C and 42.8°C. The monthly mean humidity exceeds 80% in the rainy season and about 50 to 70% in the dry season.

Most of the cyclones which were born in the Bay of Bengal attack the land of Bangladesh. However, their courses are mostly turned to the east as they move on toward the land, hence they do not seem to affect much the northwestern part of Bangladesh.

Annual rainfall in Bangladesh ranges from 1,520 mm or 60 in to 6,350 mm or 250 in and is heavy in the northeastern part and coastal zone and is relatively light in the area of the Jamuna. About 80% of the annual

Fig 4-1 Basin Map of Ganges, Brahmaputra (Jamuna) & Megna Rivers



rainfall take place in the monsoon season of May to September, about 20% fall in the other months and almost no rain in December, January and February.

In the monsoon season, river water coming from the enormous catchment area outside Bangladesh is usually superposed with the rain water fallen in the land of Bangladesh causing an extensive and severe inundation which reportedly covers about 30% of the land on the average. The area surrounding the Jamuna is habitually inudated over a width of about 100 km. The peak of the discharge of the Jamuna usually appears in July or August while that of the Ganges usually occurs in August or September. Namely there is a time lag of about one month between them. The largest discharge in the past at Bahadurabad is 76,500m^3/s or 2,700,000 cfs in 1970 and that at the Hardinge Bridge is 73,500m^3/s or 2,582,000 cfs in 1961. The maximum discharge of the Jamuna is a little larger than the Ganges.

From a geomorphological point of view, the land of Bangladesh consists of mountains (Chittagong Hills), terraces (Western Barind Terrace and Eastern Barind Terrace), a terrace formed in the Holocene Period (Tippera Surface) and alluvial plains. The alluvial plains consist of alluvial fans, natural levees or back-swamp and tidal deltas (Sundarbans).

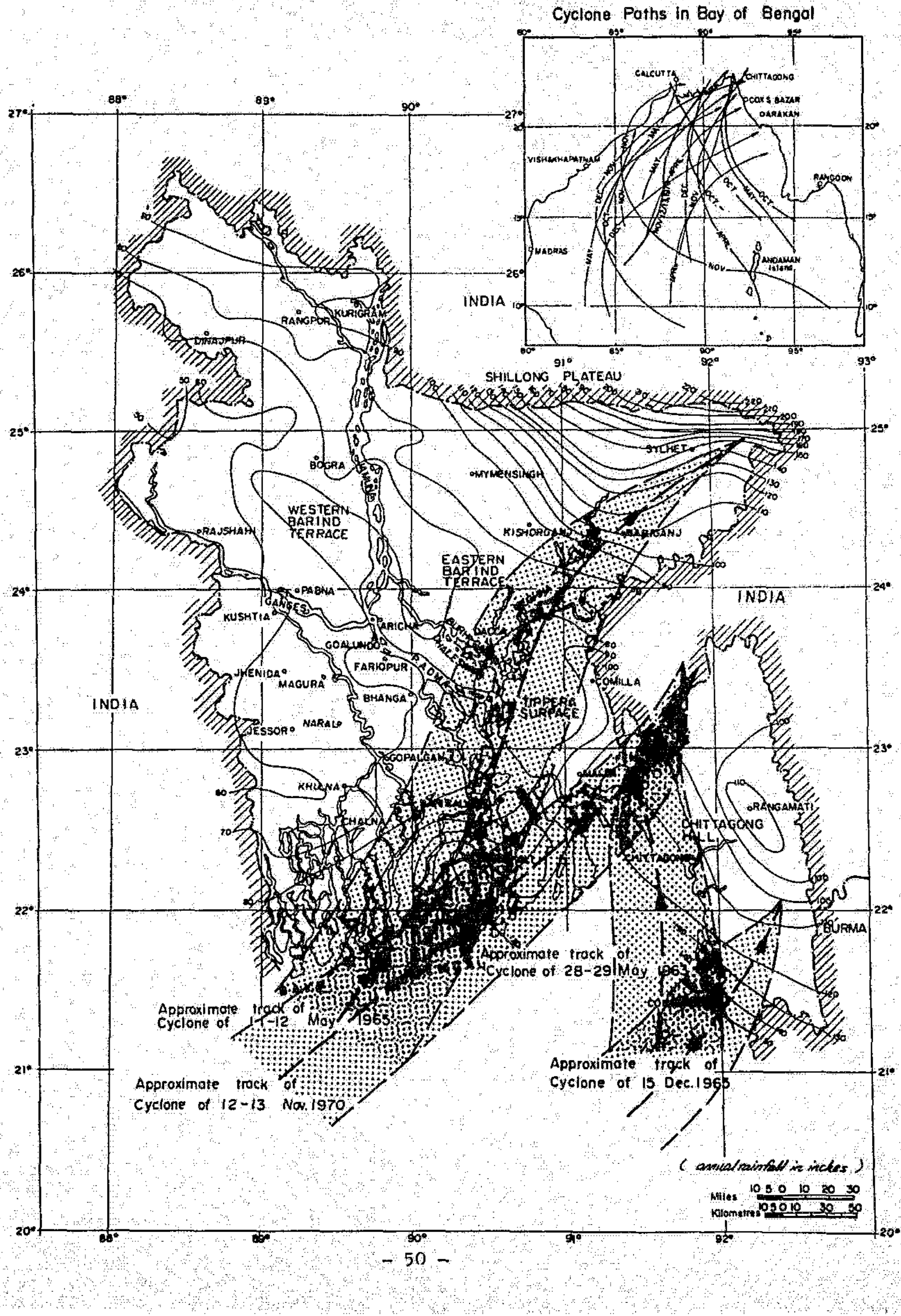
According to geological borings, there are gravel layers about 10 to 20 m thick in the plains located along the Jamuna River, about 70 m below the sea level at Aricha, about 60 m below the sea level at Sirajganj, about 40 m below the sea level at Bogra. We presume that these gravel layers were deposited during the Wurm Ice Age.

The ground movement of the region is large because the area belonged to the Alps-Himalaya Orogenic Movement Area. And the Barind Terraces are formed by the upheaval of the earth from the Pleistocene Period onward and the Tippera Surface during the Holocene Period. These terraces are surrounded by fault scarps. On the other hand, the alluvial plains along the Brahmaputra-Jamuna and Sylhet Basin are located in the ground dipping or subsiding zone.

Due to the big ground movement and the large deposition by the river, the shifting of the river course in the plain was large.

There are two explanations for the shifting of the Ganges River.

Fig. 4-2 Annual Rainfall and Cyclone Paths



One is that during ancient times, the Hooghly River was the mainstream of the Ganges and shifted from west to east. The other is that the Ganges and the Hooghly Rivers were situated as they were from ancient times. Based on the geomorphological researches in the Sundarbans Delta, we presume that, the Hooghly River became smaller and smaller whereas the Ganges River became larger.

During the time between 1720 to 1830, the Brahmaputra River shifted from the Old Brahmaputra to its present course. Before the shift, there was a small river along the present Jamuna River course and was called the Jhinai in its upper course and the Jamuna in its lower course.

There are different explanations of this diversion. Hirst attributed the diversion of the Brahmaputra to the tectonic activities, i.e., the uplift of the Barind Terrace and lowering of the valleys of the Jamuna River. La Touche suggested that the Brahmaputra diversion resulted directly from a major increase in the volume of the river water which was caused by the Brahmaputra beheading the Tsangpo River of Tibet. McIntire suggested that the diversion occurred partly because of the tilting of the eastern Barind Terrace and partly because of the shifting of the Tista River.

It cannot be believed that a big piracy such as between the Brahmaputra and the Tsangpo occurred within the last 200 years. We think that the diversion has occurred because of a combination of the tilting of the Barind Terrace, shifting of the Tista and the downwarping of the Jamuna River Valley. Due to the results of the diversion, a new alluvial fan has been formed in the old alluvial plain which consists of natural levees and back swamps. Bahadurabad and Gabargaon are located in the alluvial fan. Sirajganj is located in the natural levee area and Aricha or Nagarbari is located in the natural levee or delta region. The rivers in the alluvial fan are more unstable than that of the natural levee or delta region. And the river course near Aricha or Nagarbari is unstable because of the influence of the Genges.

There is a narrow, near Sirajganj, which is about 10 km in width and formed by the old alluvial plain and which was formed before the diversion of the Brahmaputra. But there are none or just a few old alluvail plain in the other three sites. This shows that the Sirajganj site has been stable for the last 150 years.

Fig.4 -3 Geomorphological Land Classification Map of the Jamuna River Basin

Bahadura bad, Gabargaon and it's Surrounding Area

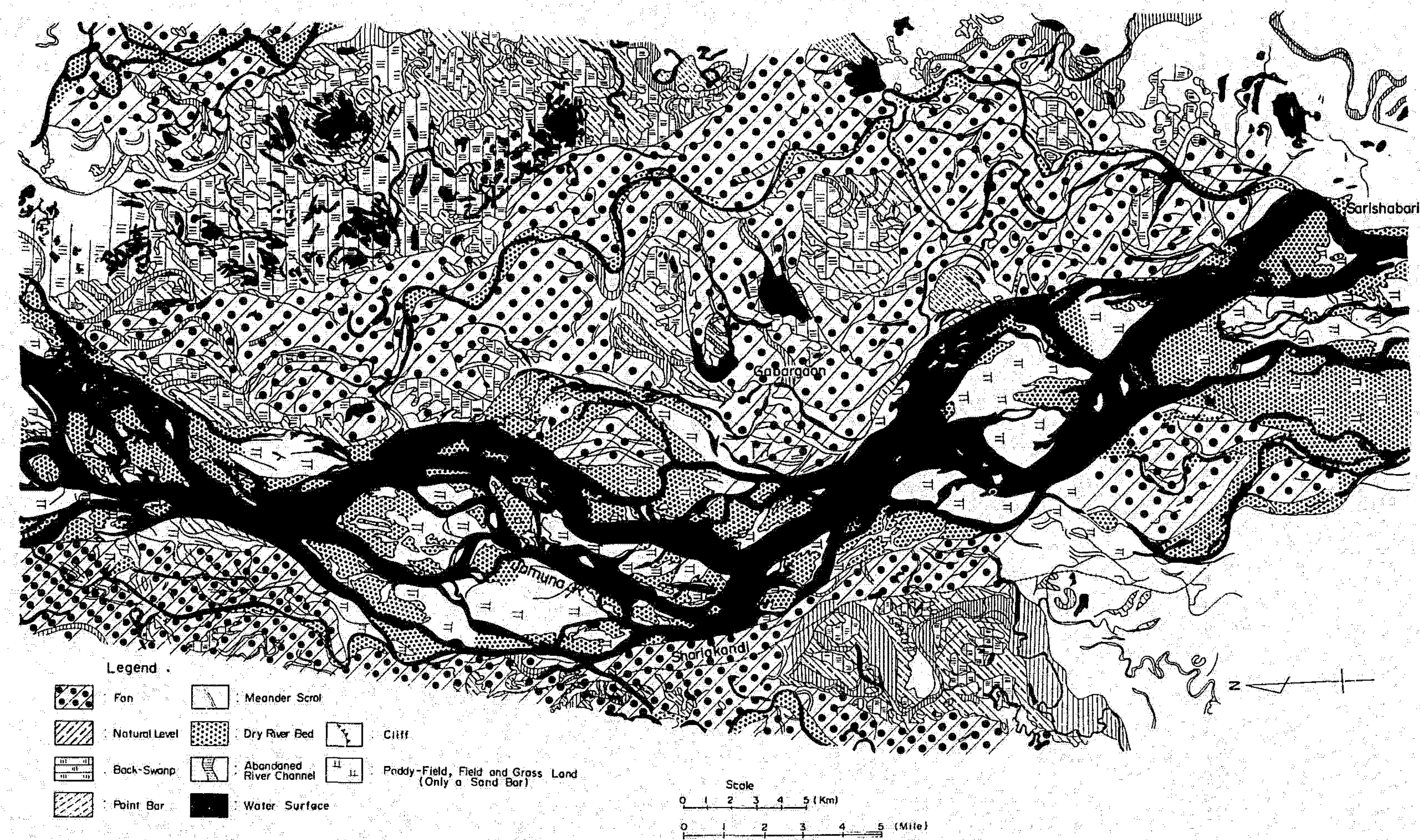
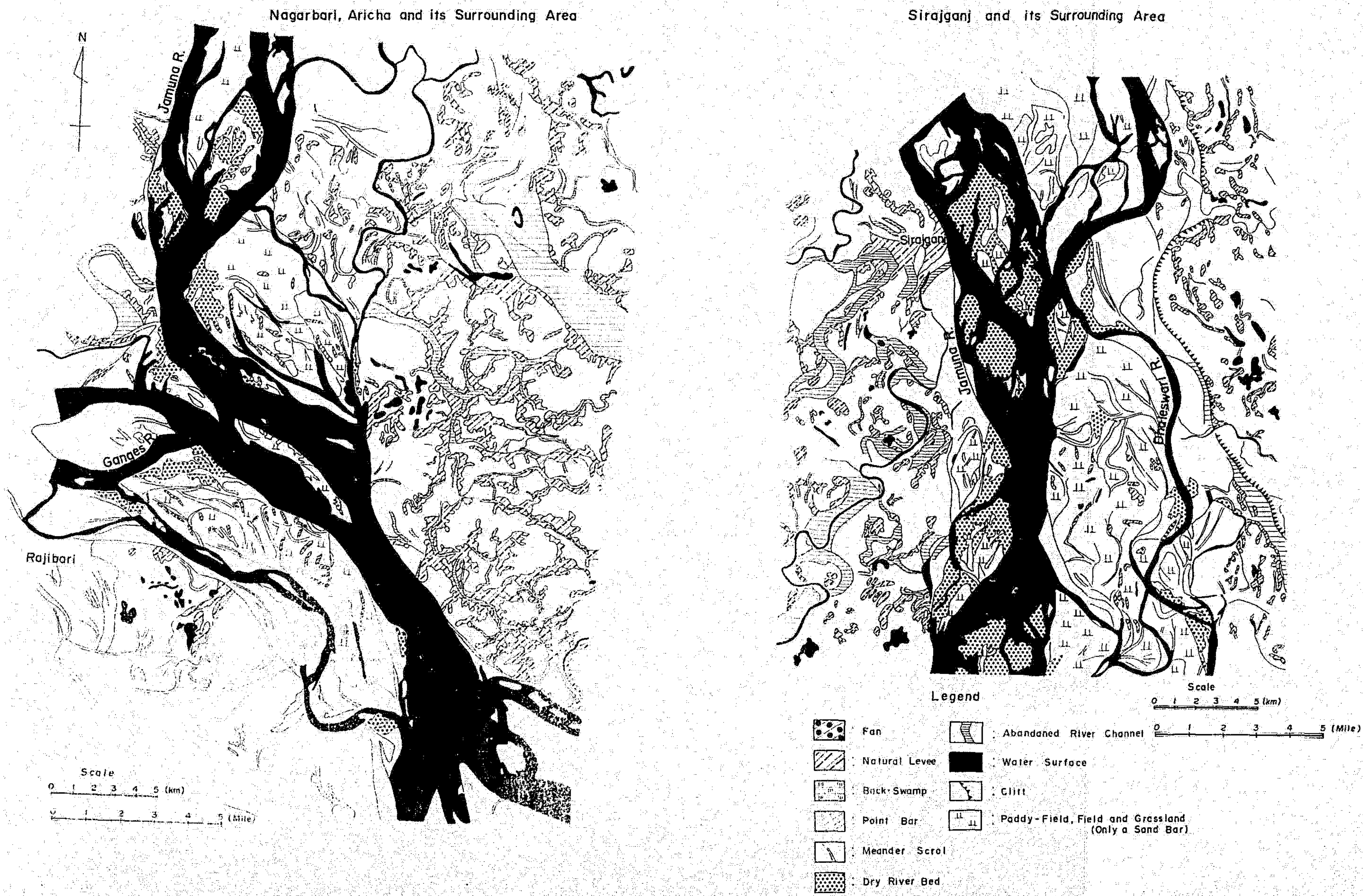


Fig.4-4 Geomorphological Land Classification Map of the Jamuna River Basin



Next, making use of the data on bank lines collected up to the present, changes of bank lines and river width were studied in reference to those in 1830. According to this study, it was found that the proposed four sites are surely located at nodes of braiding where the river width is always small compared with the other part and displacement of bank lines at the nodes except Nagarbari are almost constant except the early 30 years from 1830.

The aerophotographs taken in the dry seasons of 1952, 1963 and 1970/71 cover almost the whole stretch of the Jamuna River. Making use of these photographs, superposition was made of all waterways, which is shown in Figs. 4-6-1 and 4-6-2. This figure indicates (1) that the Jamuna River is a typically braided one, (2) that the river channels at the proposed four sites are more stable compared with the other reaches as far as the three groups of photographs are concerned and (3) that the width of the main stream in the dry season is roughly 2 km.

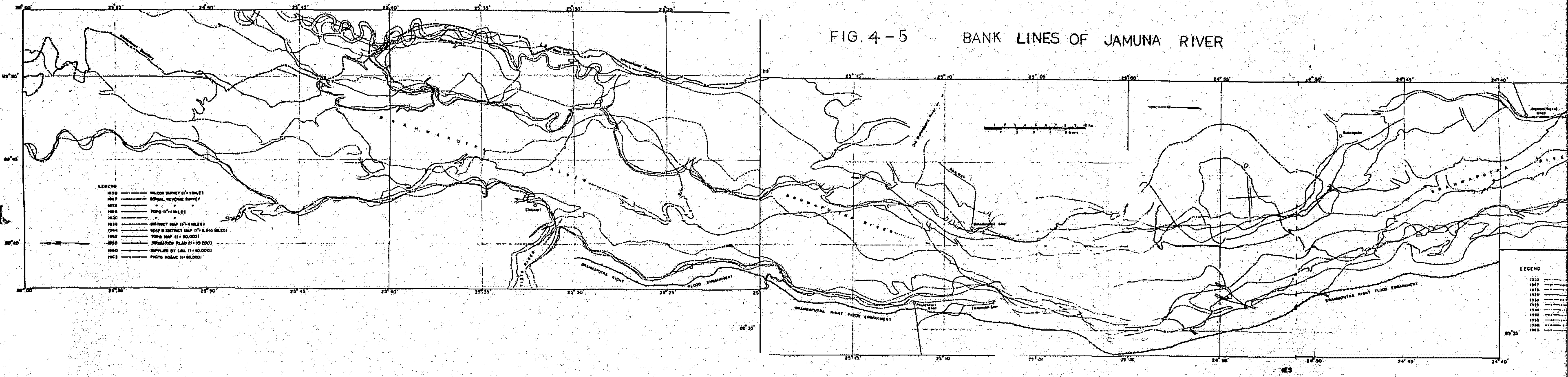
According to the data on cross levellings which were made by BWDB in 1965/66, 1966/67, 1967/68, 1968/69, 1969/70 and 1971/72, (1) the slope of the land is about 1/13,000 except 1/20,000 on the lowest stretch of 9 km,(2) the deepest river bed is almost parallel to the ground surface, namely, the maximum water depth is almost constant, about 15 m on the whole stretch of the river though it seems to have a tendency to increase slightly downwards, (3) the mean depth is almost constant, 5 m over the whole stretch, and (4) the river width and the cross-sectional area below the ground level has a tendency to increase upstream with quite large variations.

Out of the cross sections surveyed in 1965/66, 1966/67, 1967/68, 1968/69, 1969/70 and 1971/72, those near Nagarbari, Sirajganj, Gabargaon and Bahadurabad sites were selected and superposed at each site as are shown in Figs.4-8-1 to 4-8-4. These figures indicate that changes of chars and thalwegs are quite remarkable and that the thalweg is not always fixed within the same section.

3. Proposed Bridge Sites.

As is mentioned above, studies were made of natural features of the river from the viewpoints of both geomorphology and river-morphology

FIG. 4-5 BANK LINES OF JAMUNA RIVER



JAMUNA RIVER

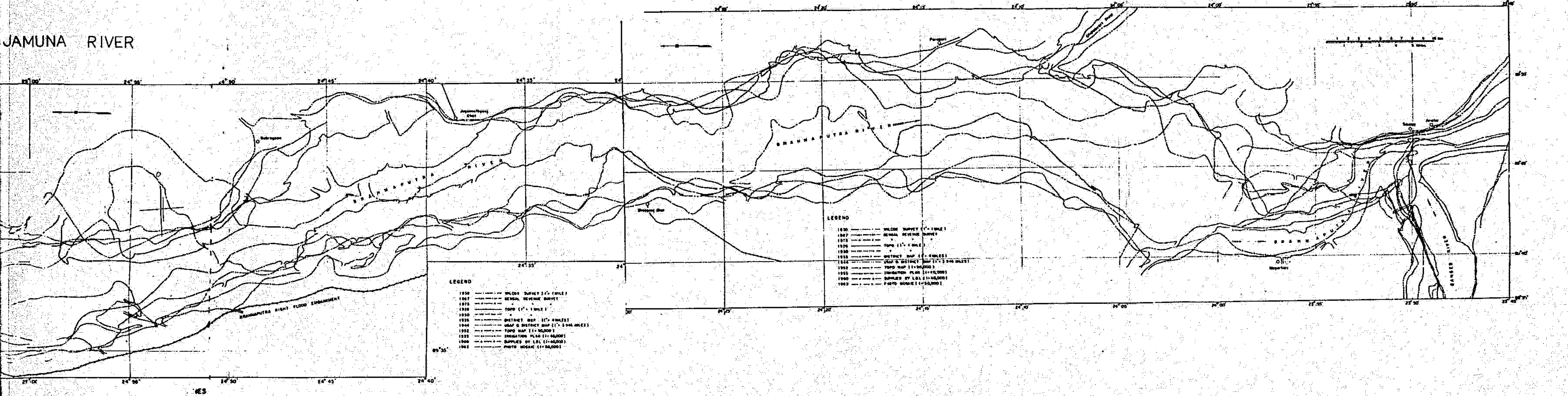


Fig. 4 - 6 - 1 Change of Waterways

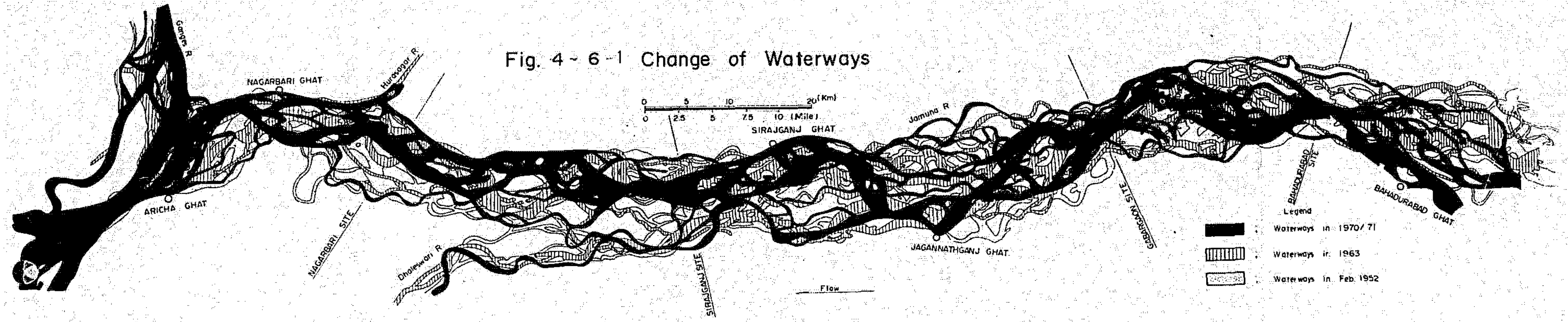


Fig. 4 - 6 - 2 Change of Waterways

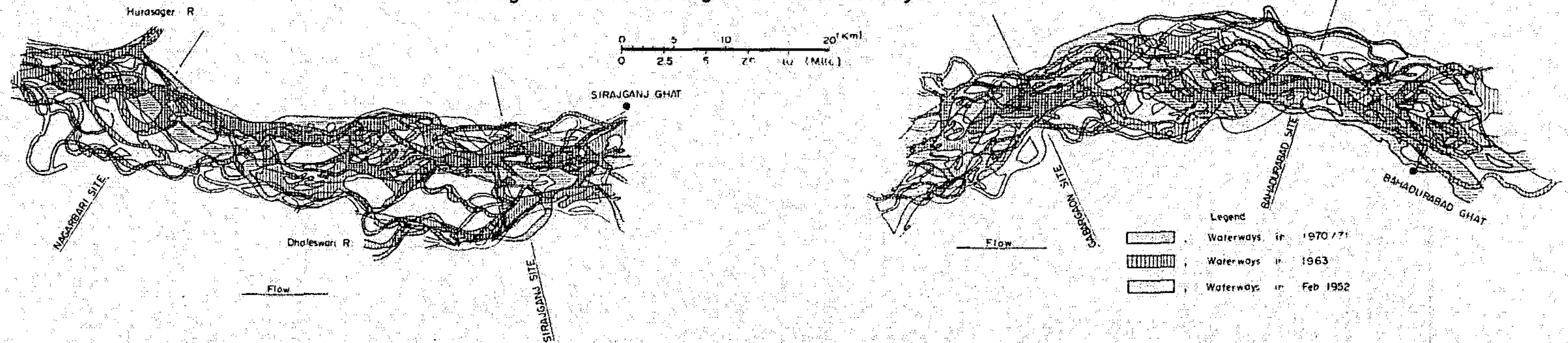


Fig. 4- Channel Features of Jamuna River

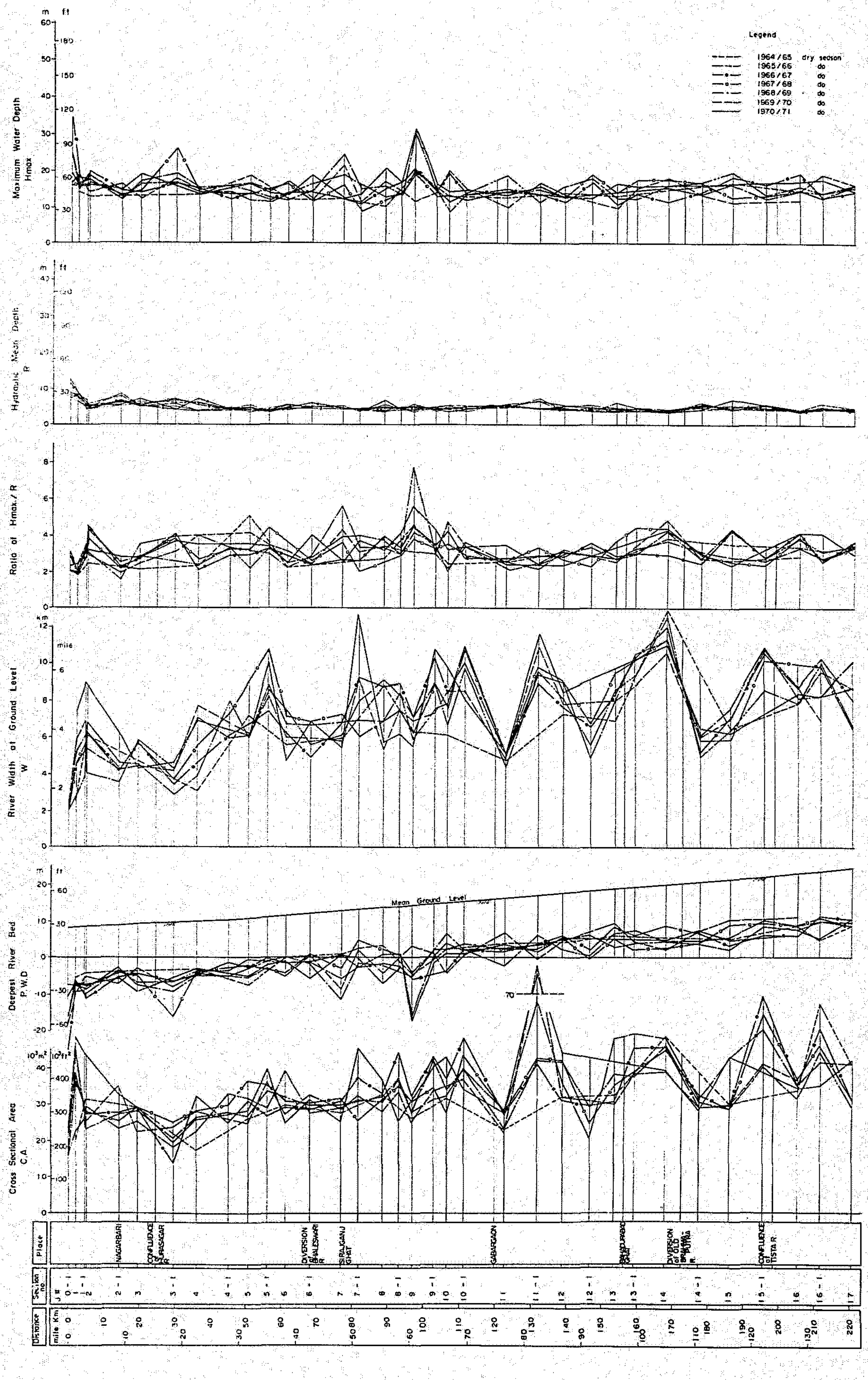


Fig. 4-8-1 Cross Section Near Nagarbari Site (J.3-1)

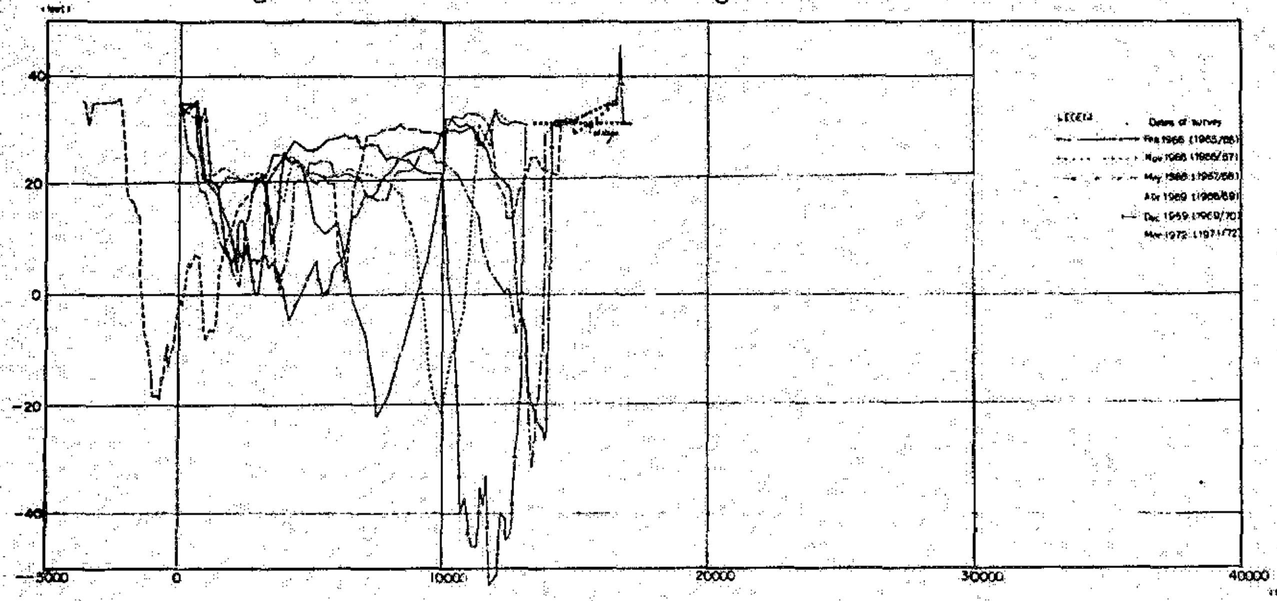


Fig. 4-8-2 Cross Section Near Sirajganj Site (J.6)

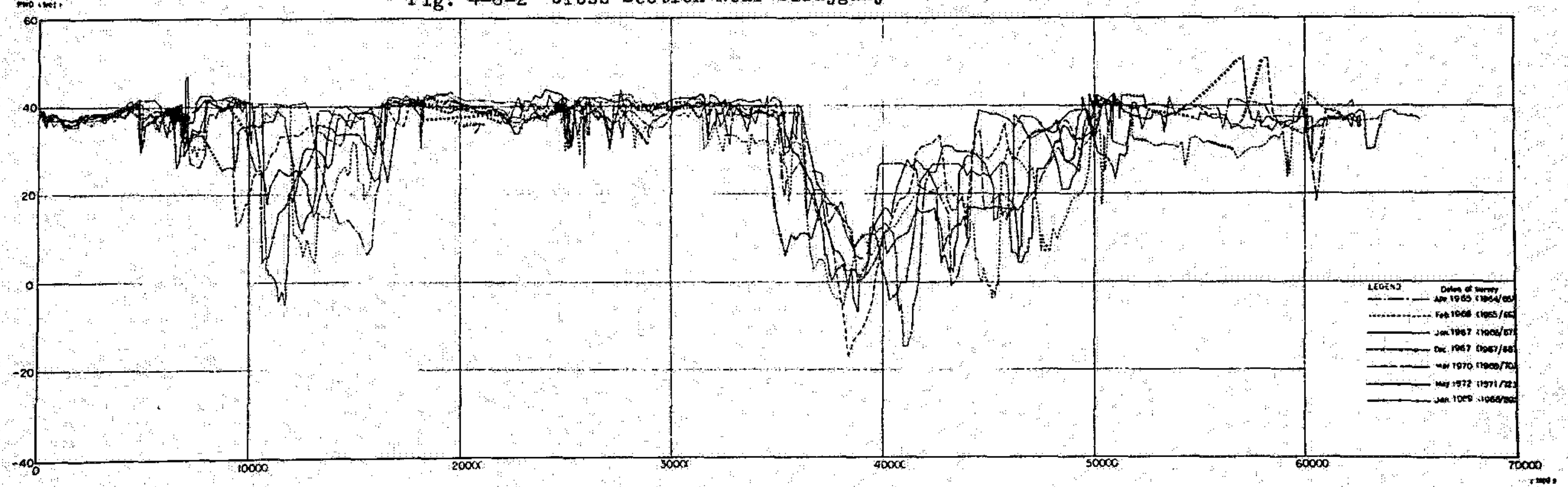


Fig. 4-8-3 Cross Section Near Gabargaon Site (J.11-1)

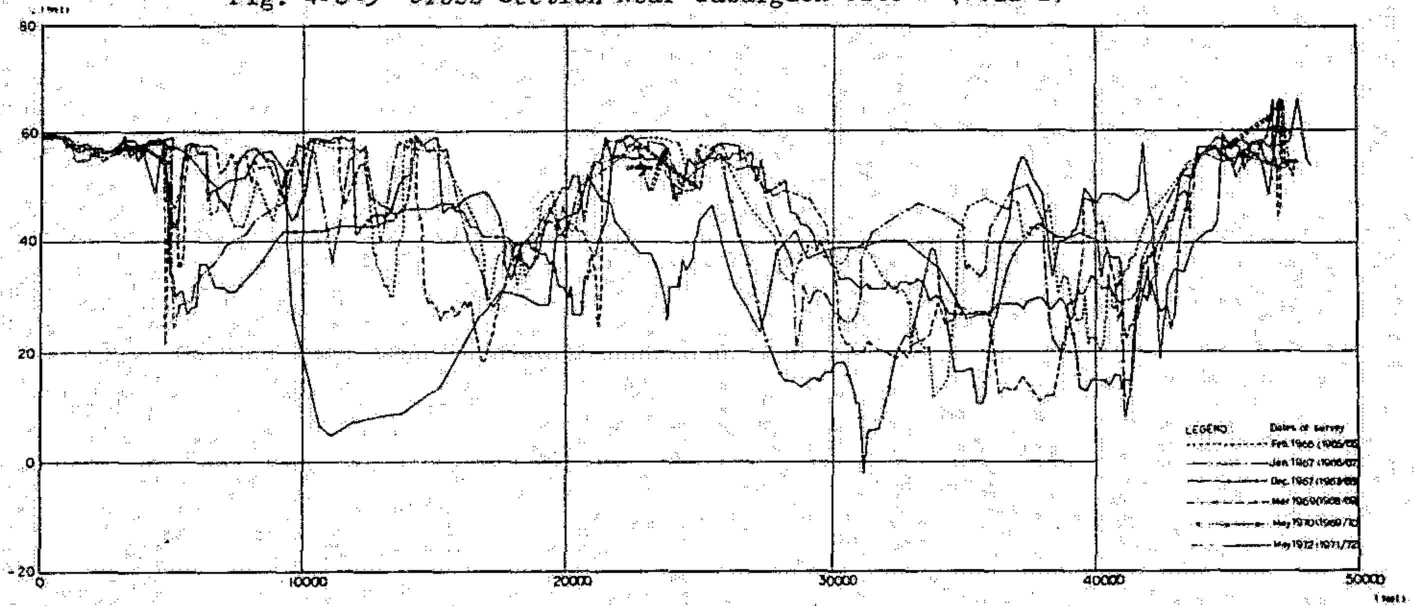
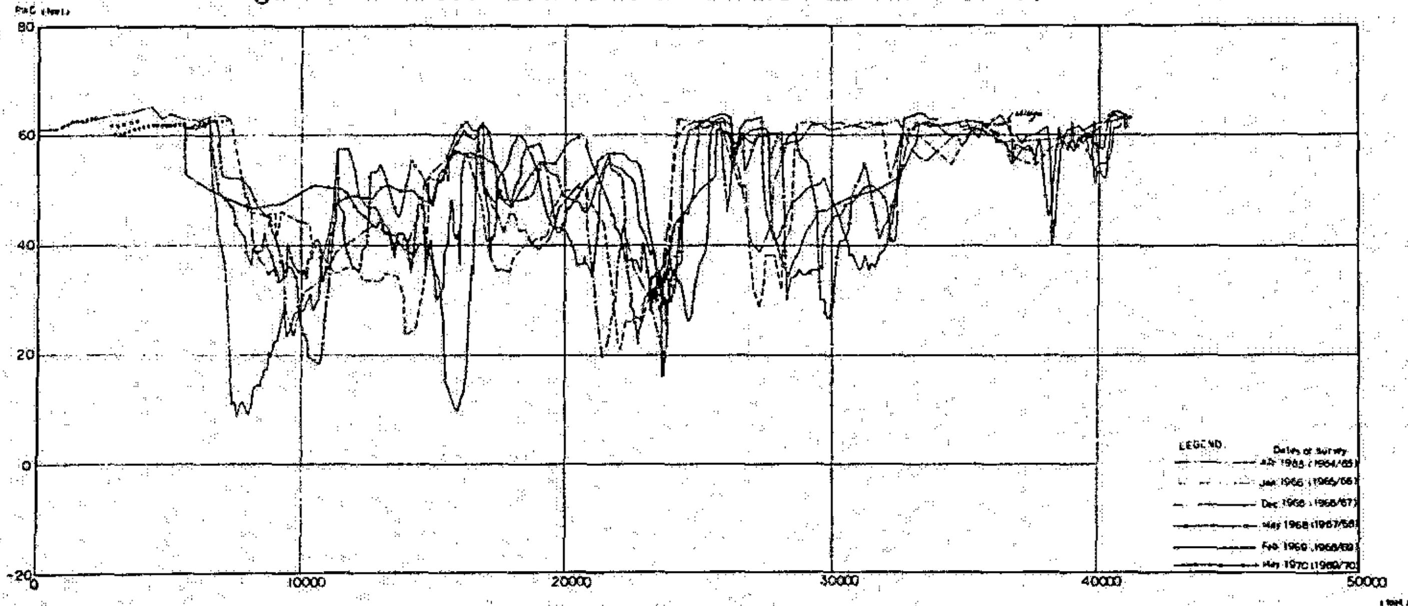


Fig. 4-8-4 Cross Section Near Bahadurabad Site (J.13)



with respect to the four sites proposed by the Prefeasibility Study Team as bridge crossing points.

From the studies, it has been found that every one of the four sites is surely located at nodes of braiding, which suggests that any of them is favorable for spanning a bridge across the river. It can be concluded, however, that, from the geomorphological point of view, the Sirajganj narrow is most stable among the four, the Gabargaon site comes closely next, the Bahadurabad site compares unfavorably with the former two and the Nagarbari site falls behind any of the others and that, from the river-morphological point of view, the Nagarbari site is the worst one while the other three are almost equal judging from the fact that the variation of the displacement of bank lines is almost constant since nearly 1860, but the Gabargaon site is best and the Bahadurabad and the Sirajganj sites are almost equal from the aspect of the size of width between the banks.

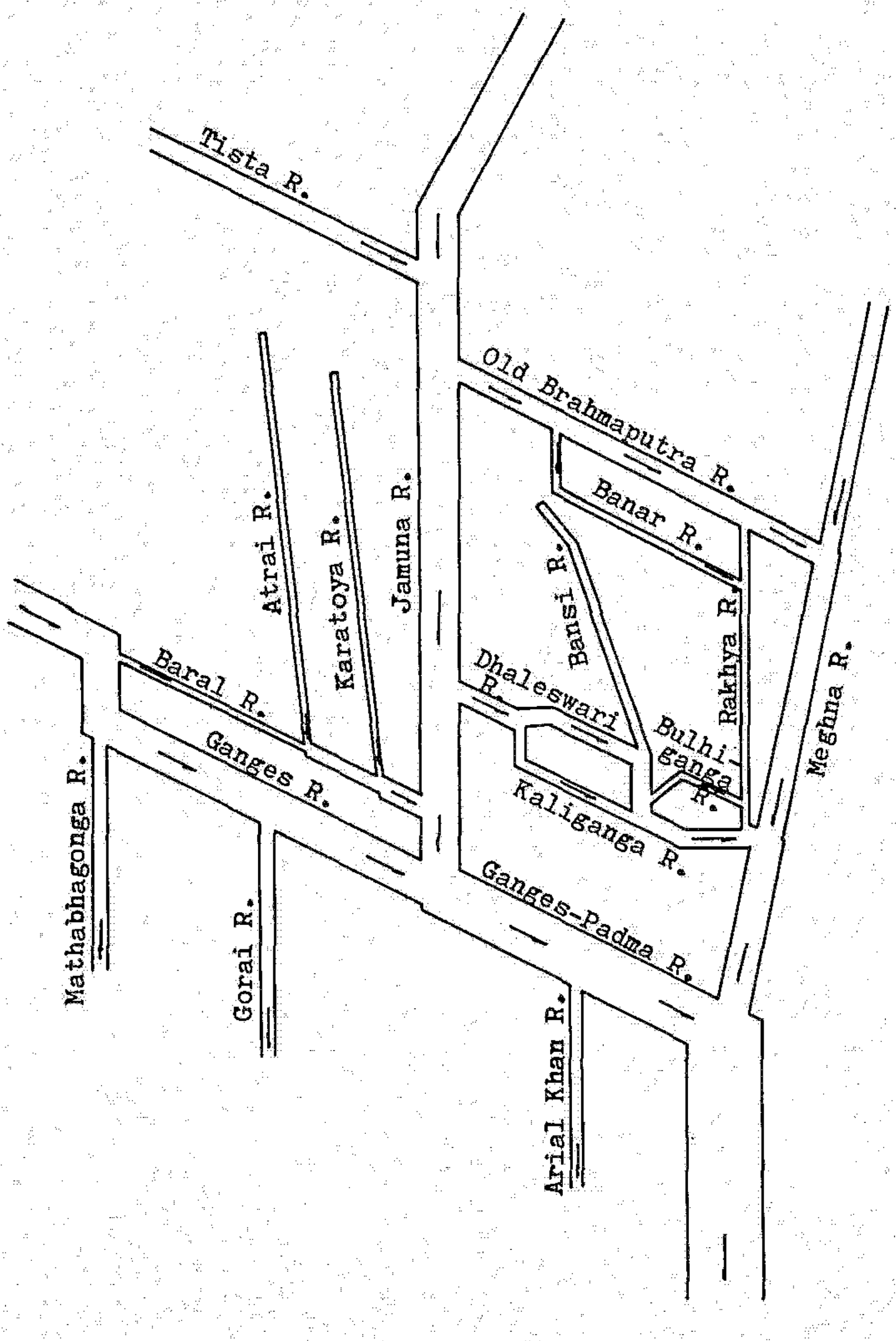
Therefore, from both the geomorphpological and the river-morphological points of view, there is nothing to choose between the two sites, Sirajganj and Gabargaon.

At the Sirajganj site, bridge axis has been chosen a little downstream of the Sirajganj narrow. This site lies under the protection of the narrow as well as the Sirajganj bank-protection works and has only one main stream with chars on both sides. This means that the site is very favorable for spanning a bridge. However, this site has also an unfavorable point that the left approach must cross one of the offtakes of the Dhaleswari. This offtake must be crossed over by a bridge or by a causeway. Fortunately, the entrances of the two offtakes lie with the bridge axis between. Therefore, it will be the best way for the bridge if the upper offtake may be closed and the lower one may be kept as the main to the Dhaleswari. In this report, crossing by a causeway has been considered so as to secure the safety of the left approach.

4. Design Discharge for Bridge Construction.

The river system of the Jamuna and the Ganges is shown schematically in Fig.4-9. Discharge measurement at Bahdurabad has been made

Fig. 4 - 9 River System around The Jamuna River



since 1956 and the station has the longest record among all the stations on the Jamuna River. Therefore, return period of flood discharges was examined at the Bahadurabad station. The results are as follows.

Return Period	Discharge	
(year)	(1,000cfs)	(1,000m^3/s)
10	2,641	74.79
20	2,774	78.56
30	2,846	80.60
40	2,895	81 99
50	2,932	83.04
60	2,962	83.89
80	3,007	85.16
100	3,042	86.15
150	3,104	87.91
200	3,147	89.12

In constructing a bridge on this river, at least, 100-year flood discharge must be taken into consideration. This dicharge is 3,042,000 cfs according to the above table. If we take 150-year flood discharge, it will be 3,104,000 cfs. This means an increment of only 2% or about 0.2 m of water depth or water stage when the discharge is assumed to be confined within embankments on both sides of the river. This magnitude of increment is within measurement error due to wind wave and change of river bed, etc. and eventually will be covered by allowance of free-board. In view of this matter, the 100-year flood discharge was taken as the design discharge for the present project.

The Bangladesh Government has already prepared Master Plan for flood Control. According to this plan, not only the Jamuna but also the Ganges and the Dhaleswari are to be confined within embankments on both sides of the rivers and the discharge of the Old Brahmaputra River is to be controled at 30,000 cfs by means of barrage. On the basis of the plan and assuming that discharge to be diverted to the Dhaleswari will follow the present rule even when left embankments were constructed along the Jamuna, the design discharge of 100-year flood was studied and allocated on the Jamuna River. Thus the disign discharges along the Jamuna are shown in Fig. 4-10.

5 . Coefficient of Roughness.

Discharges were measured by another Japanese team in the flood season of 1973 at Section N-12 near Nagarbari on Oct. 4, at section S-12 near Sirajganj on Sept.24, at section G-8 near Gabargaon on Oct.17 and at Section B-8 near Bahadurabad on Oct.11. On the basis of the measurements together with the water-stage measurements made by BWDB, coefficient of roughness in the Manning's formula was studied.

The value of coefficient n derived from flood discharge and cross sections at the same flood time is 0.020, while that derived from flood discharge and cross sections measured in a dry season nearest the flood time is 0.017. From these results, the value of n during flood is likely to be 0.020. The cause may be sought in the fact that the river depth may possibly be shallowed to a certain degree owing to sedimentation at the end of the flood. It is necessary, however, to make further study before we determine whether the coefficient of roughness is 0.020 or 0.017.

At the present study, 0.020 was used because the cross sections measured during flood were used for calculation of water levels.

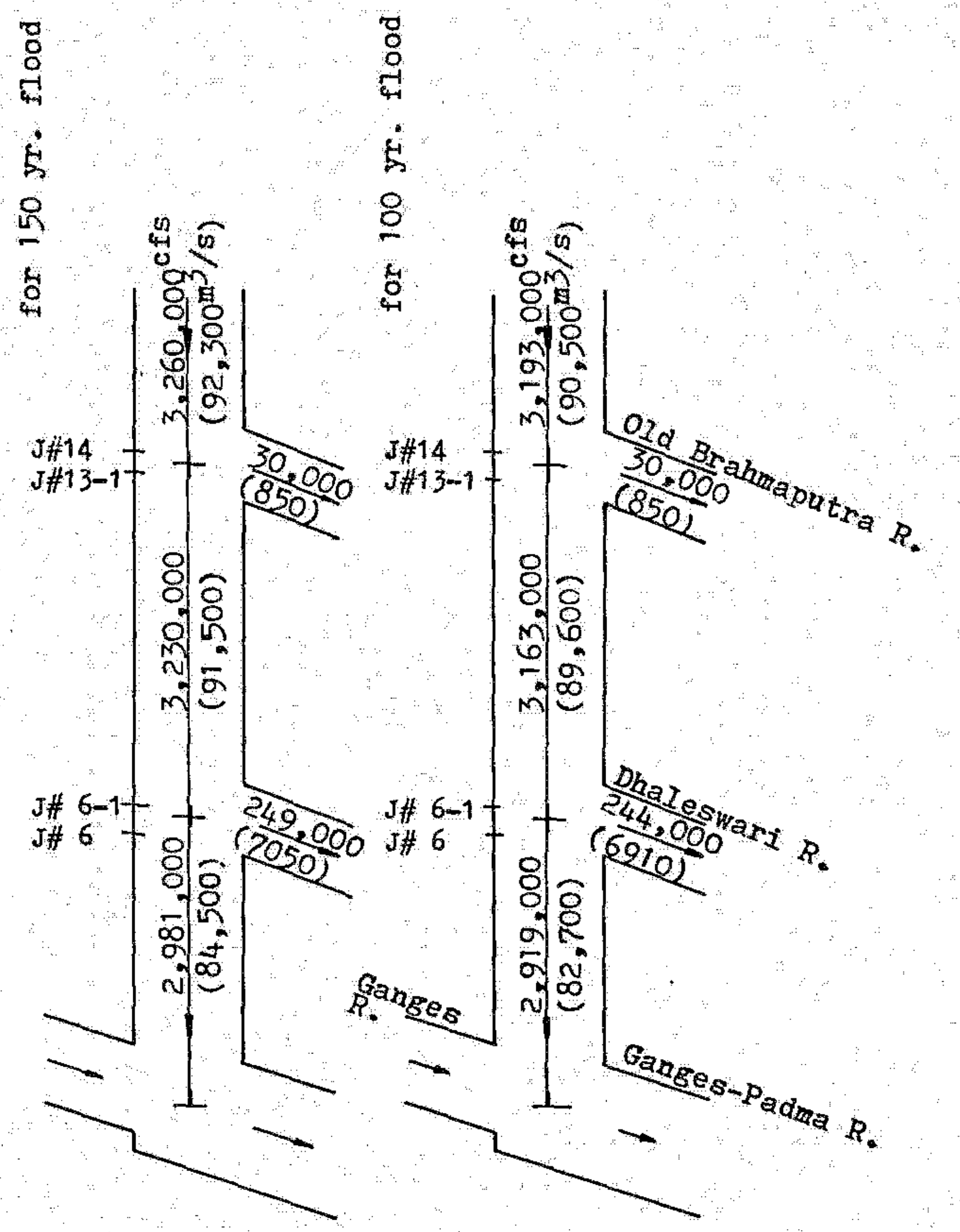
6 . Minimum River Width.

According to the Lacey's formula, the minimum width of the Jamuna River is calculated at 1,500 m assuming that the average discharge of the river is approximately 90,000 m^3/s. On the other hand, the Inglis' formula gives 2,700 m. The two formulas give a considerably large difference.

In the present study, therefore, we have to study it with regard to the natural features peculiar to the Jamuna River itself without regard to the above formulas. Based on the study of the relationship between flow areas and corresponding river widths, we have obtained a value of about 4,000 m as the minimum width corresponding to the discharge 90,000 m^3/s.

In general, a minimum river width which will minimize the costs of the works of both river training and bridge construction is desired

Fig. 4 - 10 Dischrge Allocation of Jamuna River



from the viewpoint of the total bridge-work cost. However, in the present case, it is most desirable to take a river width larger than the present state considering that we avoid influence of the bridge construction on the present state of the river and considering future possible increase in discharge which will generally take place as river improvement works go forward and future possible river plans as well as future possible change in river bed and other regime. No matter how the river width may be narrowed, it should be larger than about 4,000 m.

7. Guide Banks.

It is said, in general, that braiding of a river is associated with steeper slopes and larger sediment loads than meandering, and if the slope of a stream is excessive or the discharge is increased to a relatively large magnitude, the local rate of bank scour and deposition may be of sufficient magnitude to cause the stream to braide.

The present Jamuna River is a typical braided one. At present, we can find no sufficient study on why the Jamuna is such a braided river. However, the major causes for braiding may be sought in the matters (1) that the discharge of the Jamuna was suddenly increased by the change of the course of the Tista River, which is also regarded as one of the major causes of shifting from the Old Brahmaputra to the present Jamuna, (2) that the present Jamuna has taken its course along a depression running almost straight from north to south, which means that the slope of the Jamuna is excessively steep compared with other large rivers such as the Ganges and (3) that the length of the river in this alluvial plain is short compared with the magnitude of discharge and silt tranportation.

It is presumed that a braided river will be eventually transformed to a meandering one in the very remote future. The present Jamuna River also must have the similar nature. Even if the Jamuna should have this nature, a state of meandering will not be encountered within 100 or 200 years, because it is only less than 200 years since the Old Brahmaputra shifted its course to the present Jamuna. Therefore, the construction of bridge should be planned on the premise of braiding.

In this river, the braiding produces cliffy banks almost on the whole length of the river at least within the land of Bangladesh. The space between the both cliffy banks is regarded as an important width for flood flow.

Notwithstanding the both banks form cliffs, such clayey bank as is seen at Sara on the Ganges is not found in the Jamuna River. In other words, any portion of the bank has no resisting power to erosion. This means that any portion of the bank cannot be fixed without any artificial protection. This holds not only at loops of braiding but also at nodes.

The Japanese Preliminary Study Team recommended the four nodes of braiding as sites to be proposed for bridge crossing. This is certainly appropriate since the nodes stand at the present places at least for about a hundred years. However, this is only based upon statistics and it is very regrettable to say that, at the present stage, we cannot elucidate the reason why such nodes have been produced and stood for such a long time as a hundred years.

Although it is very appropriate to choose a node as a bridge site, we can find no guarantee that these nodes will forever stand at the same places without any change of their forms. On the contrary, the fact is that there occurs incessant erosion at banks even at the nodes of braiding ; it is a well-known fact that severe erosion occurs at the bank of Sirajganj and costly protection works are being carried out every year. Therefore, even in case a bridge is spanned at such sites from one bank to the opposite, some revetment works will be inevitable so as to protect the abuttments of the bridge.

Moreover, in every high-water season, flood water always overflows over the both banks and the lowlying land located between the two Barinds is inundated irrespective of the river and the land. This phenomenon always facilitate not only spilling to tributaries but also incessant erosion at banks. In this meaning, this river may be called a river having no banks.

Therefore, in constructing a bridge, the abuttments and the approaches should be designed so as not to be destroyed no matter what erosion may occur at banks and no matter which course the thalweg may take.

For this purpose, two artificial banks with revetments and two closing dikes connected with them are required with a view to making the flood flow run through a definite channel, namely, through a space between the two banks. In other words, the course of the flood flow should be fixed between the two banks by means of guiding function of the banks as well as by producing dead-water zones by the two closing dikes which can also be used for the road approaches to the bridge. Whether a bridge is spanned over the whole river width or a smaller one, guide banks are required together with closing dikes.

In conclusion, guide banks are needed in the case of the Jamuna River as far as a bridge is not spanned over a quite long distance which far exceeds the whole river width.

8. Design of Guide Banks.

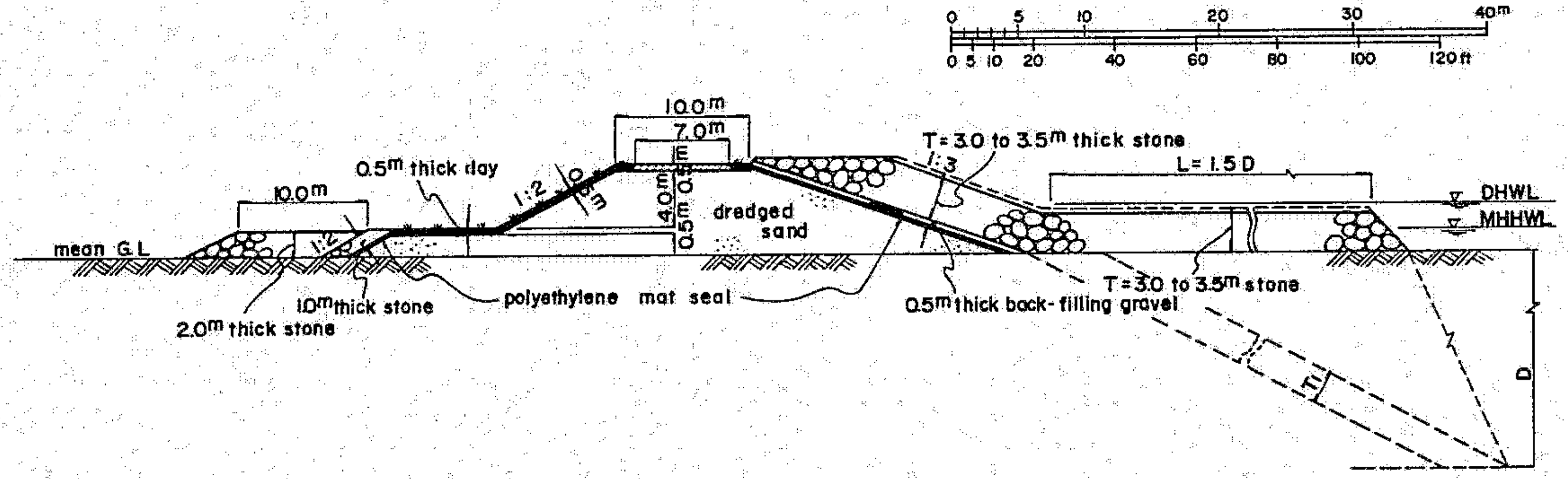
With a view to comparing the construction costs, three types of guide banks were considered at each of the four proposed sites. Type-A of guide banks was provided with a channel width (width between a pair of guide banks) of 2,000 m which is a minimum value at places where waterways are integrated into one during the dry season. Type-B was provided with a channel width of about 4,000 m, or the minumum value of river width which is expected to appear when the design discharge runs without spilling. Type-C was provided with a channel width of about 5,500 m which is the river width between both natural banks and varies a little at each site. The three types of guide banks and the closing dikes were disposed as are shown in Figs. 4-12-1 to 4-12-4.

The design high water level was calculated on the assumption that the design discharge does not spill and the coefficient of roughness is 0.02. The water levels at the four bridge sites are as follow.

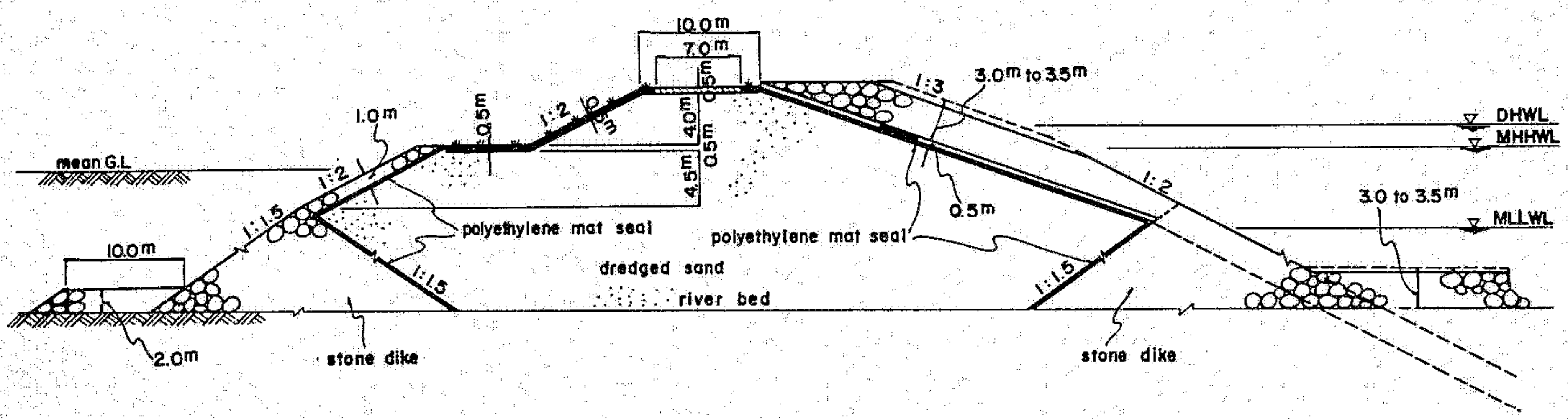
Nagarbari site	:	DHWL = 14.01 m, PWD at Sect. N-13
Sirajganj site	:	DHWL = 15.24 m, PWD at Sect. S-11
Gabargaon site	:	DHWL = 19.44 m, PWD at Sect. G-10
Bahadurabad site	:	DHWL = 20.86 m, PWD at Sect. B- 9

Fig. 4-11 shows the standard cross sections of guide banks in which the freeboard was determined at 3 m considering possible variation of the design discharge, change in river bed, wind wave, etc. and considering the practice in the right flood embankment. The crown width was determined at 10 m considering the convenience of construction works and maintenance after the completion.

Fig. 4-11 Standard Cross Section of Guide Bank (Scale 1/500)



(In case of deep water)



The length of the guide banks were designed after Gales'. These are also shown in Figs. 4-12-1 to 4-12-4.

The falling-apron type was adopted as the apron of the guide banks and designed as shown in Fig. 4-11 in consideration of the lowering of the river bed which will occur between a pair of guide banks and further lowering due to a possible eccentricity of the thalweg. The size of stones for the apron was studied and so-called one-man stone was afirmed to be safe enough, while stones from 60 to 100 kg were recommended for pitching on the slopes.

9. Closing Dikes.

The closing dikes were designed to support the function of the guide banks and are shown in Figs. 4-12-1 to 4-12-4. The standard cross section is given in Fig. 4-13-2.

10. Scour at Bridge Piers.

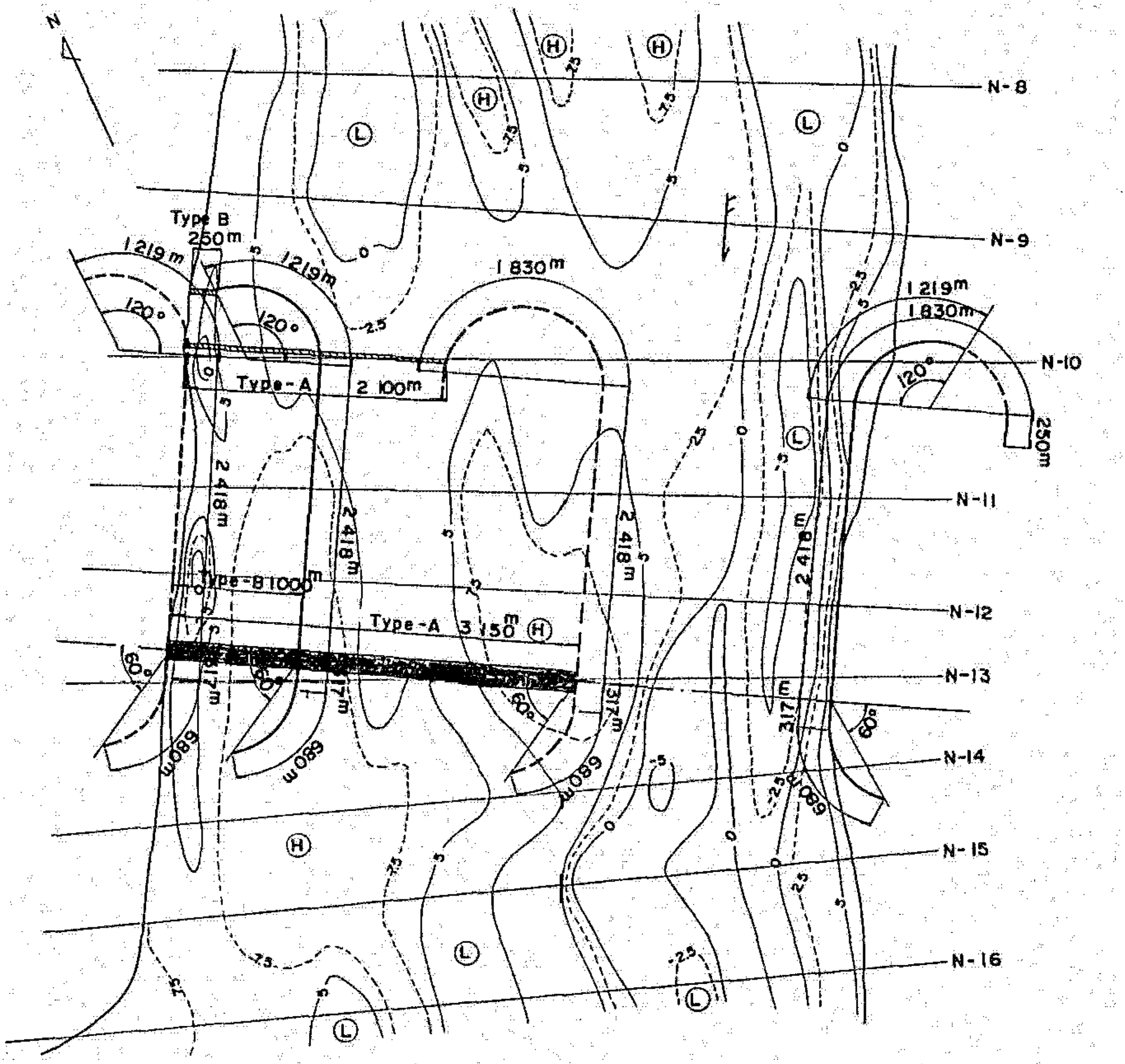
Depth of scour at piers was studied using several formulas and is shown in Fig. 4-14. As is seen in this figure, these formulas give a very wide range of values. It can be said, however, (1) that Andru's formula cannot hold with regard to piers of small diameter since the scoured depth depends on water depth alone, (2) that Laursen's formula may hold with regard to piers of larger diameter because the formula was obtained for the range of H/b = 1 to 7 where H denotes water depth and b is width of a pier, (3) that Breuser's and Larras' formulas seem to be unreasonable at least in case of larger diameter because these formulas are independent of water velocity as well as bed material and relate to pier width alone, but they seem to hold with regard to piers of small diameter such as pipes, and (4) that Shen's formula seems to hold over a considerably wide range of pier width.

After all, in our judgement, Andru's formula is applicable to a pier width larger than about 10 m and Shen's formula is applicable to a pier width smaller than about 3 m in the case of the Jamuna River.

If we adopt a well type as substructure, the width or the diameter is supposed to be of the order of 12 m. Tables 4-1-1 to 4-1-4 show diameter and weight of stones capable of resisting to the flow which will be expected to occur at the bottom of prospective scour hole. In this

Fig. 4-12-1 Location of Guide Bank, Closing Dike and Closing Works

SITE : Nagarbari



SCALE : 1 / 50,000

0 1 2 3 4 5km

0 0.5 1 2 3 mile

LEGEND :

- ——— : Type - A (Guide bank)
- ——— : Type - B (Guide bank)
- - - - - : Type - C (Guide bank)
- ▬ : Closing dike
- ▭ : Closing work
- —·— : Bridge axis

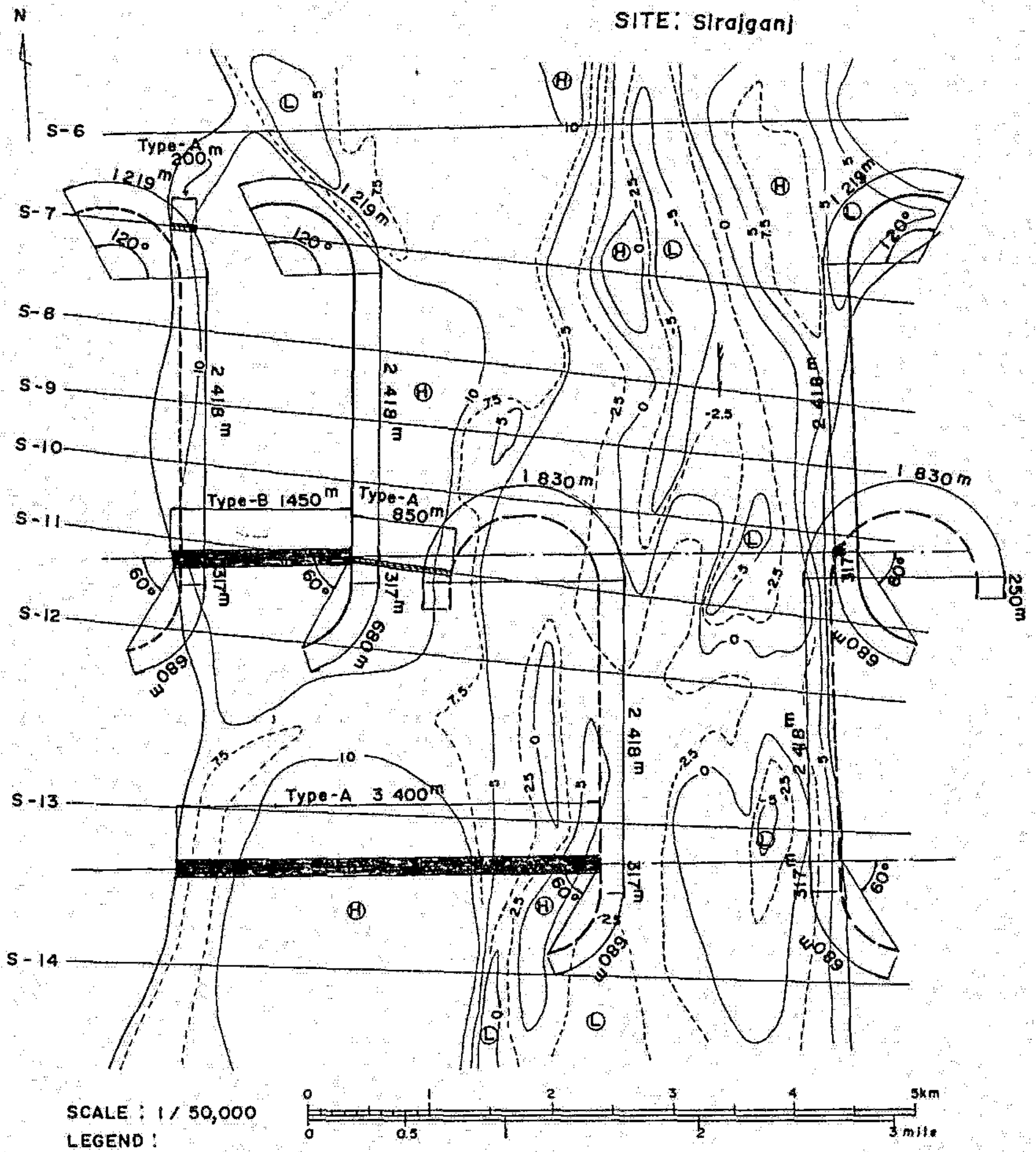
DIMENSION : (unit : m)

TYPE	Guide bank		Closing dike		Closing work	
	Channel width	Length	Right side	Left side	Right side	Left side
A	2 000	5 495 x 2	3 150	0	2 100	0
B	4 200	4 634 x 2	1 000	0	250	0
C	5 200	4 634 x 2	0	0	0	0

CONTOUR LINE : in m, PWD.

Fig. 4-12-2 Location of Guide Bank, Closing Dike and Closing Works

SITE: Sirajganj



SCALE : 1 / 50,000

LEGEND :

- ———— : Type-A } Guide bank
- ———— : Type-B
- ------ : Type-C
- ▬▬ : Closing dike
- ▭▭ : Closing work
- —·— : Bridge axis

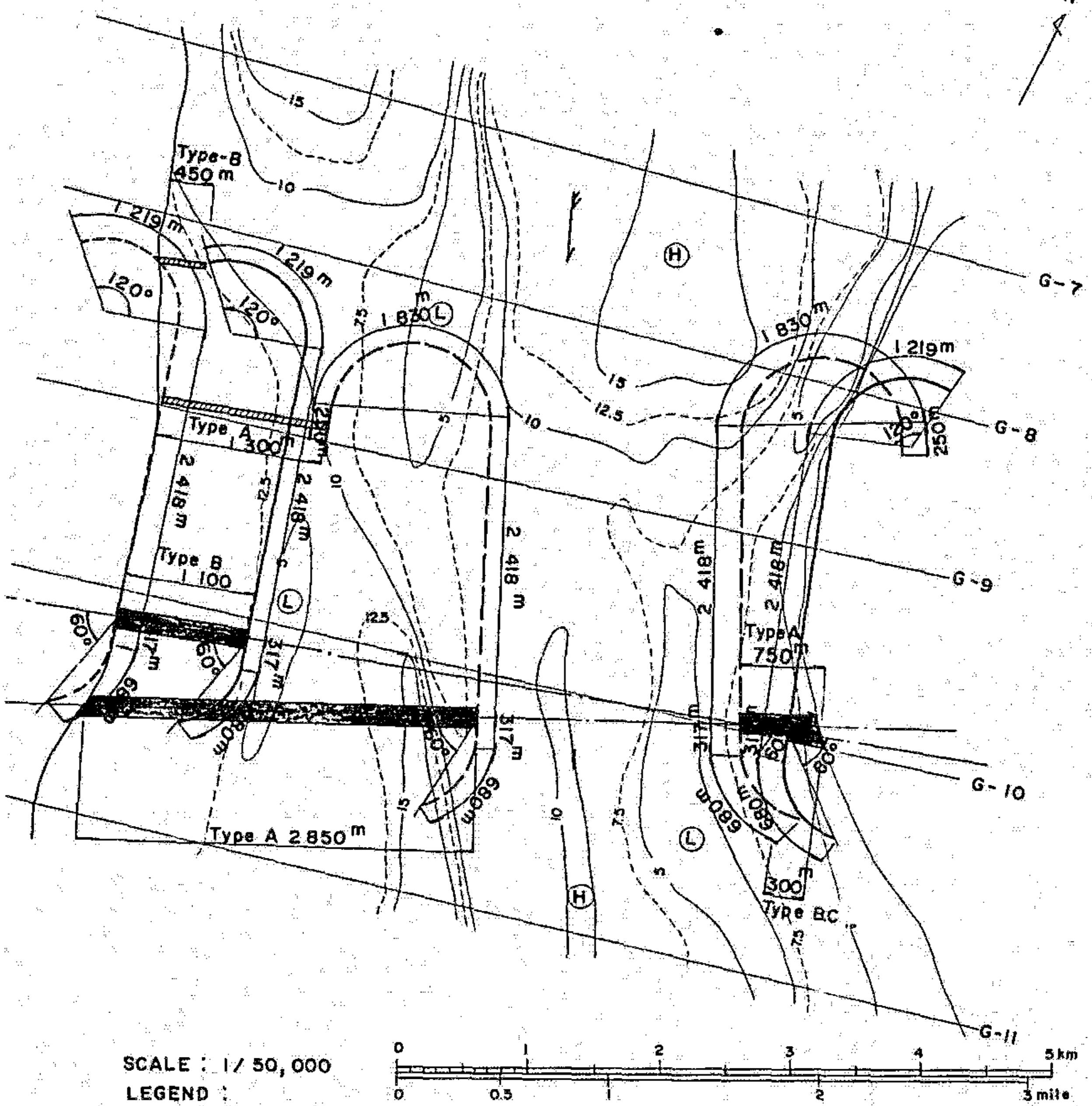
DIMENSION : (unit : m)

TYPE	Guide bank		Closing dike		Closing work	
	Channelwidth	Length	Right side	Left side	Right side	Left side
A	2 000	5 495 x 2	3 400	0	1 050	0
B	4 200	4 634 x 2	1 450	0	200	0
C	5 600	4 634 x 2	0	0	0	0

CONTOUR LINE : in m, PWD.

Fig.4-12-3 Location of Guide Bank,Closing Dike and Closing Works

SITE : Gabargaon



SCALE : 1/50,000

LEGEND :

- ——— : Type - A
- ——— : Type - B
- - - - : Type - C

(Type - A, Type - B and Type - C: Guide bank)

- ▬▬ : Closing dike
- ▭▭ : Closing work
- —·— : Bridge axis

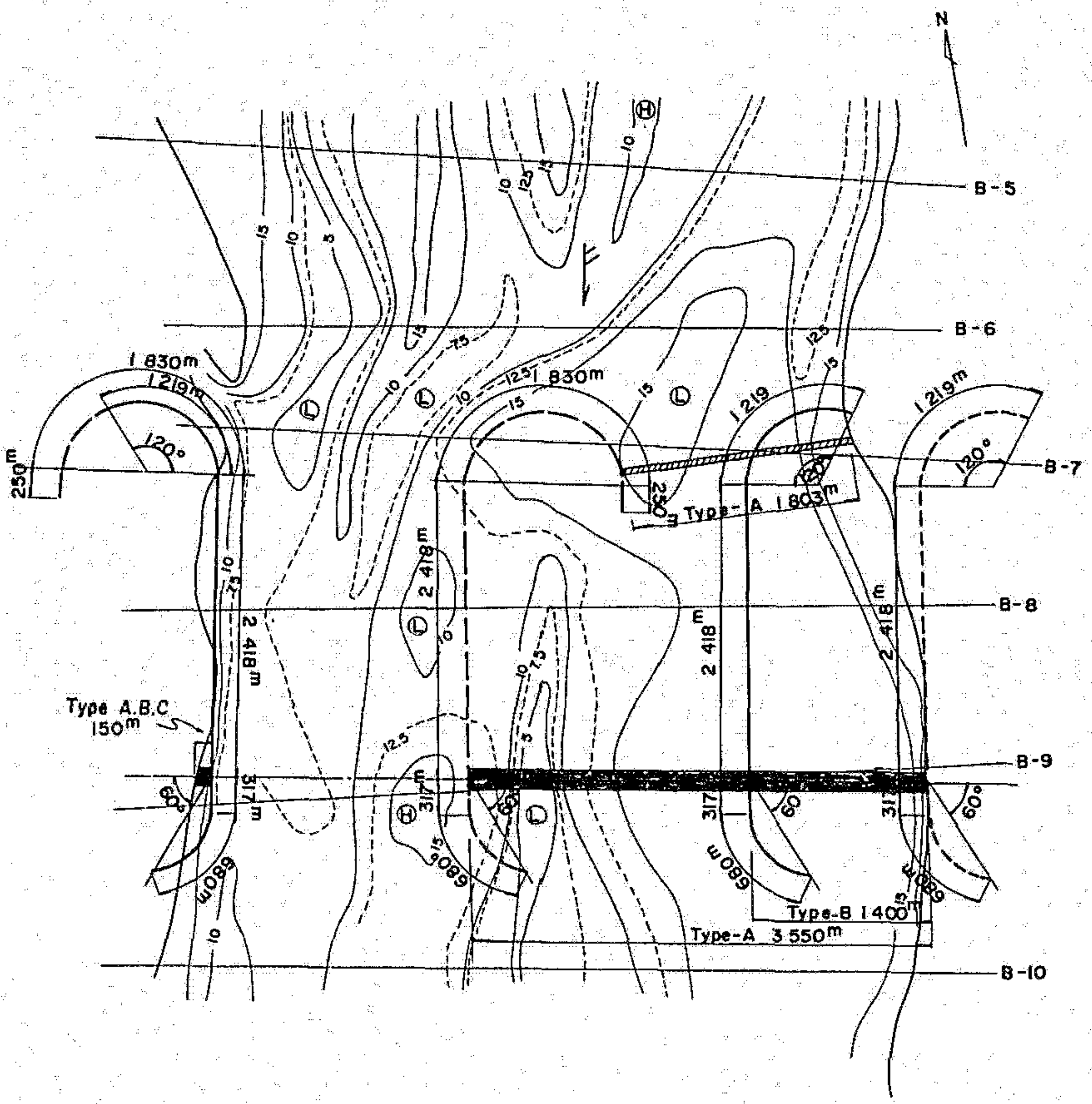
DIMENSION : (unit : m)

TYPE	Guide bank		Closing dike		Closing work	
	Channel width	Length	Right side	Left side	Right side	Left side
A	2 000	5 495 x 2	2 850	750	1 300	0
B	4 200	4 634 x 2	1 100	300	450	0
C	5 200	4 634 x 2	0	300	0	0

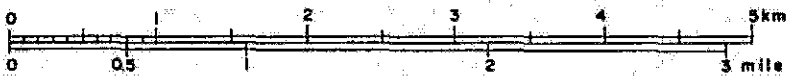
CONTOUR LINE : in m, PWD.

Fig.4-12-4 Location of Guide Bank, Closing Dike and Closing Works

SITE : Bahadurabad



SCALE : 1 / 50,000



LEGEND :

- ——— : Type – A
- ——— : Type – B
- ------ : Type – C

} Guide bank

- : Closing dike
- : Closing work
- —·— : Bridge axis

DIMENSION : (unit : m)

TYPE	Guide bank		Closing dike		Closing work	
	Channel Width	Length	Right side	Left side	Right side	Left side
A	2 000	5 495 x 2	150	3 550	0	1805
B	4 200	4 634x 2	150	1 400	0	0
C	5 600	4 634 x 2	150	0	0	0

CONTOUR LINE : in m , PWD.

Fig. 4-13-1 Typical Cross Section of Approach Road (Scale 1/2,000)

(Double track railway & four lane road, in the vicinity of guide bank)

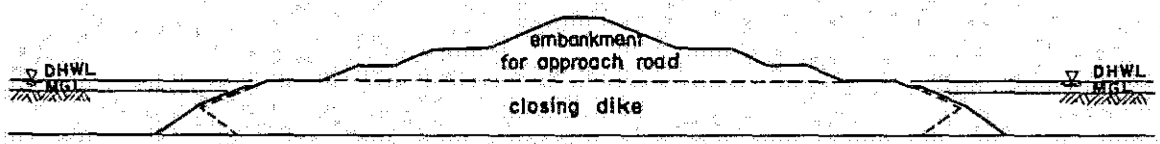


Fig. 4-13-2 Standard Cross Section of Closing Dike (Scale 1/500)

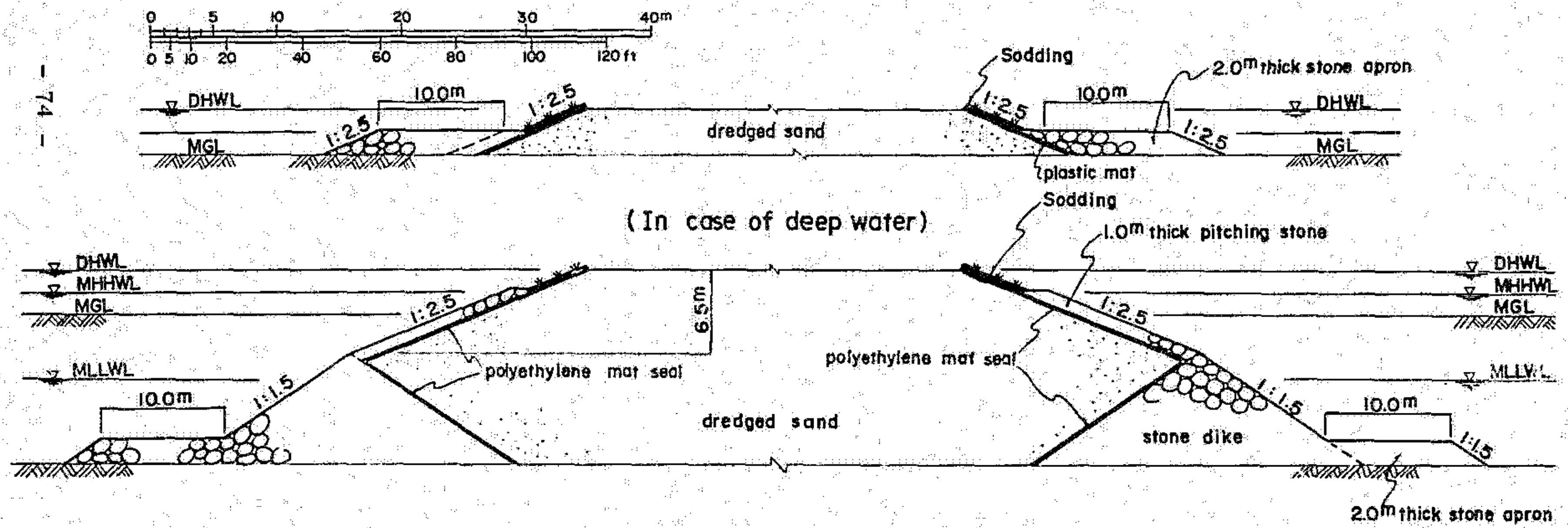


Fig. 4-14 Scoured Depth around Bridge Pier

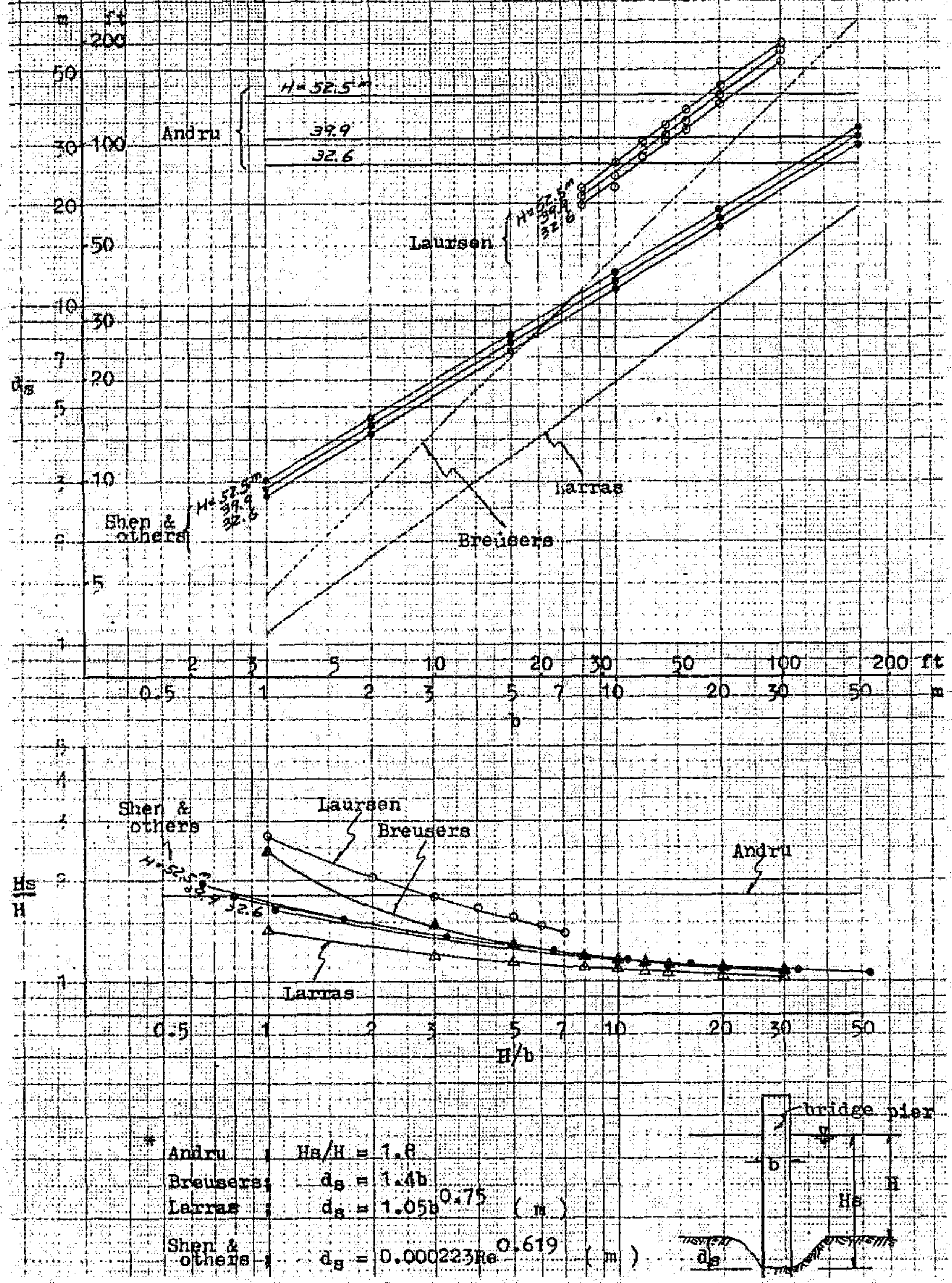


Table 4-1-1 Weight of Stones

Site: Nagarbari

Type	B (m)	v_m (m/s)	H (m)	v (m/s)	H' (m)	H/H'	d (m)	W (t)
A	2,000	1.993	56.139	3.871	Hs = 101.050 Hs/H = 1.8			
					56.139	1	1.352	3.429
					67	0.838	0.950	1.190
					78	0.720	0.701	0.480
					89	0.631	0.538	0.216
					101.050	0.556	0.418	0.101
B	4,200	1.580	42.384	3.573	Hs = 76.291 Hs/H = 1.8			
					42.384	1	1.152	2.121
					50	0.848	0.828	0.788
					59	0.718	0.594	0.291
					68	0.623	0.447	0.125
					76.291	0.556	0.356	0.063
C	5,200	1.468	36.825	3.319	Hs = 66.285 Hs/H = 1.8			
					36.825	1	0.997	1.379
					44	0.837	0.696	0.468
					51	0.722	0.518	0.193
					58	0.635	0.401	0.090
					66.285	0.556	0.307	0.041

Table 4-1-2 Weight of Stones

Site: Sirajganj

A	2,000	2.246	53.862	4.356	Hs = 96.952 Hs/H = 1.8			
					53.862	1	1.712	6.959
					60	0.898	1.381	3.653
					70	0.769	1.013	1.442
					80	0.673	0.776	0.648
					96.952	0.556	0.529	0.205
B	4,200	1.780	40.749	4.026	Hs = 73.348 Hs/H = 1.8			
					40.749	1	1.463	4.343
					50	0.815	0.971	1.270
					60	0.679	0.674	0.425
					70	0.582	0.495	0.168
					73.348	0.556	0.452	0.128
C	5,600	1.625	33.473	3.676	Hs = 60.251 Hs/H = 1.8			
					33.473	1	1.220	2.518
					40	0.837	0.854	0.864
					50	0.669	0.546	0.226
					60	0.558	0.380	0.076
					60.251	0.556	0.377	0.074

Table 4-1-3 Weight of Stones

Site: Gabargaon

Type	B (m)	v_m (m/s)	H (m)	v (m/s)	H' (m)	H/H'	d (m)	W (t)
A	2,000	2.209	54.891	4.291	Hs = 98.804		Hs/H = 1.8	
					54.891	1	1.662	6.370
					65	0.844	1.184	2.303
					76	0.722	0.866	0.901
					87	0.631	0.662	0.403
					98.804	0.556	0.514	0.188
B	4,200	1.767	41.041	3.997	Hs = 73.874		Hs/H = 1.8	
					41.041	1	1.442	4.160
					49	0.838	1.012	1.438
					57	0.720	0.748	0.581
					65	0.631	0.574	0.262
					73.874	0.556	0.446	0.123
C	5,200	1.648	35.554	3.728	Hs = 63.997		Hs/H = 1.8	
					35.554	1	1.254	2.736
					42	0.847	0.900	1.011
					49	0.726	0.661	0.403
					56	0.635	0.506	0.180
					63.997	0.556	0.388	0.081

Table 4-1-4 Weight of Stones

Site: Bahadurabad

A	2,000	2.400	50.542	4.662	Hs = 90.976		Hs/H = 1.8	
					50.542	1	1.961	10.479
					60	0.842	1.391	3.807
					70	0.722	1.022	1.481
					80	0.632	0.783	0.669
					90.976	0.556	0.606	0.309
B	4,200	1.925	37.682	4.354	Hs = 67.828		Hs/H = 1.8	
					36.682	1	1.711	6.962
					45	0.837	1.199	2.400
					52	0.725	0.899	1.011
					60	0.628	0.675	0.429
					67.828	0.556	0.529	0.207
C	5,600	1.742	31.229	3.940	Hs = 56.212		Hs/H = 1.8	
					31.229	1	1.401	3.824
					37	0.844	0.998	1.379
					43	0.726	0.738	0.558
					50	0.625	0.547	0.228
					56.212	0.556	0.433	0.113

table, H' denotes a water depth of the scour in a state on the way to the equilibrium.

Bridge piers should be sunk down deep enough to stand by themselves without any protection around them. If there are some reasons that this is very difficult or too uneconomical, we may have to consider some protection works though it is never desired. In this case, the values given in the above table will be usefull for design.

If we do not want to allow any scour around piers, it is theoretically necessary to place stones larger than those given in the table with respect to non-scour. In practice, however, stones smaller than these may serve if necessary supply for maintenance is considered.

If a pier be sunk down deep enough to have a required grip length from the bottom of the equilibrium scour hole, it is of course unnecessary to place stones in the hole, because, in the state of equilibrium, the scoured hole will be supplied with sediment by water flow and hold a definite equilibrium depth. The values given in the tables mean the sizes of stones which will not be moved without the supply of sediment.

If we want to reduce scoure depth or hold a depth H' smaller than the depth in equilibrium, it will be necessary to place stones of the order of sizes calculated in the tables with regard to scoured depth H'. Also in this case, stones smaller than these will serve if we consider the continuous supply of sediment to the hole and maintenace supplement of stones.

Since the sizes of stones given in the tables are those capable of resisting to the maximum velocity at the pier wall, it may be allowed to use smaller stones on the downstream side of the pier.

It will be appropriate to take 2D as the range of protection from the pier wall where D is the diameter of the pier and it will be necessary to provide the same thickness of protection as in the case of the apron to prevent the leakage of sand through voids of the placed stones.

11. Construction Works for River Training.

River training works which consist of construction of guide banks, closing dikes and closing works shall be completed in two years. Since the construction area will be submerged during the flood season, one guide bank and related structures on one side shall be completed in one dry season in order to avoid losses of construction materials and works due to washing away in under-construction portion.

It is a very important problem for this type of river training works to extract required amount of stones and transport them to the work sites as economically and efficiently as possible. It is regrettable, however, that the problem is not solved yet from unavoidable circumstances and is scheduled to be studied continually. Therefore, it was assumed in this study that the quantity of stones required for the river training works is obtainable at specified stock yards and at any time specified.

Quantity of works of guide banks, closing dikes and closing works is shown in Tables 4-2-1, 4-2-2 and 4-3. The quantity of materials shown in the tables contains the allowances for settlement and losses during the construction, but the materials of closing dikes given here do not contain those of the portion above the design high water level and those of the approaches outside the river banks. Those materials of the closing dikes and the approaches outside the river which are not given in this chapter are included in the chapter of the bridge planning.

Work period in a year was assumed at about seven months from November to May in the dry season and the total construction period for river training works was assumed to be two years.

The bank body will be built mainly with dredged sand, polyethylene mats for prevention of sand from being carried away and stones for protection of the body from scouring.

Stone pitching will basically be carried-out on the ground; (1) loading by tractor shovels, (2) carrying by dump trucks and (3) pitching by man power. But in the sections where ground work is impossible, another method of execution will be used; (1) loading by tractor shovels and dump trucks, (2) carrying by bottom hopper barges and (3) placing in the water from barges. Fig.4-15 shows flow of construction works of apron and body of guide banks.

Table 4-2-1 Quantity of Works

Site: Nagarbari

	Works	Condition	Unit	Type A Left	Type A Right	Type B Left	Type B Right	Type C Left	Type C Right
Guide bank	Embankment	O.G.	km	5.5	2.8	4.6	4.6	4.6	4.6
		U.W.	km	0	2.7	0	0	0	0
		Σ	km	5.5	5.5	4.6	4.6	4.6	4.6
	Apron	O.G.	km	5.5	2.8	4.6	4.6	4.6	4.6
		U.W.	km	0	2.7	0	0	0	0
		Σ	km	5.5	5.5	4.6	4.6	4.6	4.6
	Pavement		km	5.5	5.5	4.6	4.6	4.6	4.6
Closing dike		O.G.	km	0	2.10	0	0.50	0	0
		U.W.	km	0	1.05	0	0.50	0	0
		Σ	km	0	3.15	0	1.00	0	0
Closing works		O.G.	km	0	2.1	0	0.25	0	0
		U.W.	km	0	0	0	0	0	0
		Σ	km	0	2.1	0	0.25	0	0
Construction road		O.G.	km	5.5	9.7	3.2	4.6	3.2	4.6
		U.W.	km	0	2.2	1.4	2.0	1.4	0
		Σ	km	5.5	11.9	4.6	6.6	4.6	4.6
Jetty			nos.	(0)	6 (6)	(0)	1 (1)	(0)	0 (0)

Site: Sirajganj

	Works	Condition	Unit	Type A Left	Type A Right	Type B Left	Type B Right	Type C Left	Type C Right
Guide bank	Embankment	O.G.	km	5.5	1.0	4.6	4.6	4.6	4.6
		U.W.	km	0	4.5	0	0	0	0
		Σ	km	5.5	5.5	4.6	4.6	4.6	4.6
	Apron	O.G.	km	5.5	1.0	4.6	4.6	4.6	4.6
		U.W.	km	0	4.5	0	0	0	0
		Σ	km	5.5	5.5	4.6	4.6	4.6	4.6
	Pavement		km	5.5	5.5	4.6	4.6	4.6	4.6
Closing dike		O.G.	km	0	2.30	0	1.45	0	0
		U.W.	km	0	1.10	0	0	0	0
		Σ	km	0	3.40	0	1.45	0	0
Closing works		O.G.	km	0	1.05	0	0.20	0	0
		U.W.	km	0	0	0	0	0	0
		Σ	km	0	1.05	0	0.20	0	0
Construction road		O.G.	km	5.5	12.3	3.3	6.9	3.3	1.5
		U.W.	km	0	0.6	1.3	0.5	1.3	3.1
		Σ	km	5.5	12.9	4.6	7.4	4.6	4.6
Jetty			nos.	(0)	10 (10)	(0)	0 (0)	(0)	0 (0)

O.G. : Works on the ground

U.W. : Works under water

Σ : Sum of O.G.andU.W.

Table 4-2-2 Quantity of Works

Site: Gabargaon

	Works	Condition	Unit	Type A Left	Type A Right	Type B Left	Type B Right	Type C Left	Type C Right
Guide bank	Embankment	O.G.	km	1.4	0.3	4.6	4.6	4.6	4.6
		U.W.	km	4.1	5.2	0	0	0	0
		Σ	km	5.5	5.5	4.6	4.6	4.6	4.6
	Apron	O.G.	km	1.4	0.3	4.6	4.6	4.6	4.6
		U.W.	km	4.1	5.2	0	0	0	0
		Σ	km	5.5	5.5	4.6	4.6	4.6	4.6
	Pavement		km	5.5	5.5	4.6	4.6	4.6	4.6
Closing dike		O.G.	km	0.30	1.95	0.75	1.10	0	0
		U.W.	km	0.45	0.90	0	0	0	0
		Σ	km	0.75	2.85	0.75	1.10	0	0
Closing works		O.G.	km	0	1.30	0	0.45	0	0
		U.W.	km	0	0	0	0	0	0
		Σ	km	0	1.30	0	0.45	0	0
Construction road		O.G.	km	5.5	10.7	3.0	4.2	3.0	4.6
		U.W.	km	0	1.2	1.6	2.4	1.6	0
		Σ	km	5.5	11.9	4.6	6.6	4.6	4.6
Jetty			nos.	(9) 11	(11)	(0) 0	(0)	(0) 0	(0)

Site: Bahadurabad

	Works	Condition	Unit	Type A Left	Type A Right	Type B Left	Type B Right	Type C Left	Type C Right
Guide bank	Embankment	O.G.	km	3.7	5.5	4.6	4.6	4.6	4.6
		U.W.	km	1.8	0	0	0	0	0
		Σ	km	5.5	5.5	4.6	4.6	4.6	4.6
	Apron	O.G.	km	3.7	5.5	4.6	4.6	4.6	4.6
		U.W.	km	1.8	0	0	0	0	0
		Σ	km	5.5	5.5	4.6	4.6	4.6	4.6
	Pavement		km	5.5	5.5	4.6	4.6	4.6	4.6
Closing dike		O.G.	km	3.10	0.15	1.40	0.15	0	0.15
		U.W.	km	0.45	0	0	0	0	0
		Σ	km	3.55	0.15	1.40	0.15	0	0.15
Closing works		O.G.	km	1.80	0	0	0	0	0
		U.W.	km	0	0	0	0	0	0
		Σ	km	1.80	0	0	0	0	0
Construction road		O.G.	km	11.9	5.5	7.4	4.6	4.6	4.6
		U.W.	km	0.8	0	0	0	0	0
		Σ	km	12.7	5.5	7.4	4.6	4.6	4.6
Jetty			nos.	(6) 6	(0)	(0) 0	(0)	(0) 0	(0)

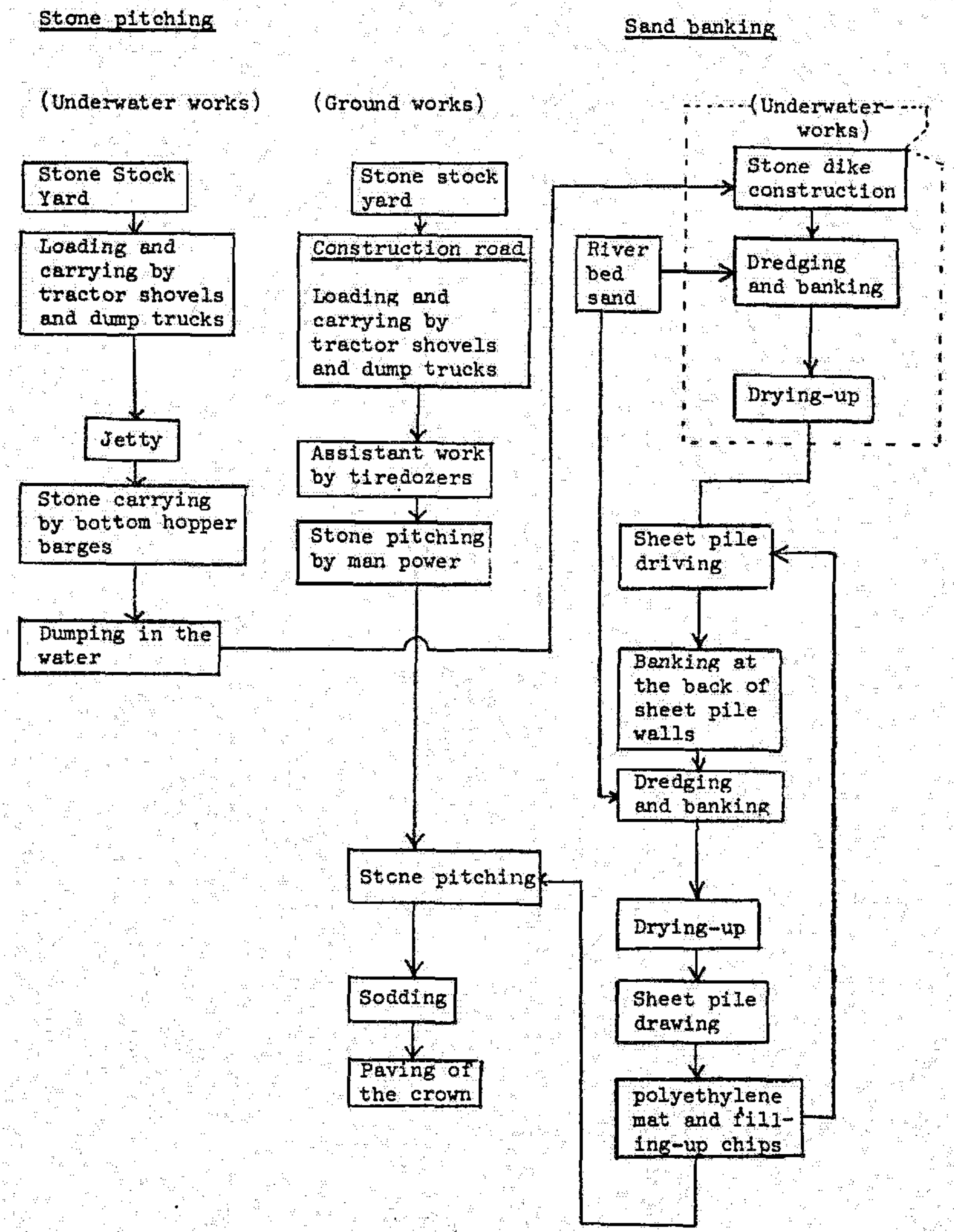
O.G. : Works on the ground
U.W. : Works under water
Σ : Sum of O.G.andU.W.

Table 4 – 3 Quantity of Materials

Site	Type	Unit	Guide bank		Closing dike		Total	
			Stone	Dredged sand	Stone	Dredged sand	Stone	Dredged sand
Bahadurabad	B	10^3 m^3 ($10^6 ft^3$)	2,520 (89.0)	2,630 (92.9)	90 (3.2)	1,330 (47.0)	2,610 (92.2)	3,960 (139.9)
	C	10^3 m^3 ($10^6 ft^3$)	2,230 (78.8)	2,530 (89.4)	10 (0.4)	240 (8.5)	2,240 (79.1)	2,770 (97.8)
Gabargaon	B	10^3 m^3 ($10^6 ft^3$)	2,850 (100.7)	4,000 (141.3)	150 (5.3)	1,600 (56.5)	3,000 (106.0)	5,600 (197.8)
	C	10^3 m^3 ($10^6 ft^3$)	2,460 (86.9)	2,500 (88.3)	20 (0.7)	470 (16.6)	2,480 (87.6)	2,970 (104.9)
Sirajganj	B	10^3 m^3 ($10^6 ft^3$)	2,620 (92.5)	2,510 (88.6)	100 (3.5)	1,130 (39.9)	2,720 (96.1)	3,640 (128.6)
	C	10^3 m^3 ($10^6 ft^3$)	2,340 (82.6)	3,150 (111.2)	– (–)	– (–)	2,340 (82.6)	3,150 (111.2)
Nagarbari	B	10^3 m^3 ($10^6 ft^3$)	2,940 (103.8)	4,270 (150.8)	130 (4.6)	1,620 (57.2)	3,070 (108.4)	5,890 (208.0)
	C	10^3 m^3 ($10^6 ft^3$)	2,520 (89.0)	3,240 (114.4)	– (–)	– (–)	2,520 (89.0)	3,240 (114.4)

* Stones do not include chip

Fig.4-15 Flow of Construction Works of Guide Banks



Dredged sand will be banked after having been poured into blocks to be formed by sheet-pile partition walls. The length of one block shall be 500 m. Height of banking shall be 1.5 m at a time. In underwater sections, stone dikes will be built up to a height of 1.0 m above the low water level and then dredged sand will be put between the stone dikes.

Principal construction machinery required for these works will be as follows.

Tractor shovels, dump trucks, tire dozers, bull dozers, vibro-pile drivers, crawler cranes, engine dynamos, bottom-hopper barges and pump dredgers.

12. Construction Costs for River Training Works.

The construction costs for river training works of three types at the four sites were roughly estimated on the following condition and, among them, two cases for type B and C alone are shown in Table 4-4 since it was decided that a total span less than about 4,000 m will not be taken into consideration. But they do not contain costs of general facilities such as living quarters, motor pools, fuel storage, material storage, cargo-handling facilities at the sites and electric power supply system for general facilities.

a. According to the first-stage survey of the quarry study team, unit price of stones when they are delivered at the stock yards at the four sites of Bahadurabad, Gabargaon, Sirajganj and Nagarbari was temporarily assumed at 6 TK/ft^3, 6.3 TK/ft^3, 7 TK/ft^3 and 7.4 TK/ft^3 respectively.

b. Unit prices in general were assumed based on the results of the price survey as of the end of March of 1974.

c. Rent of principal construction machinery was calculated according to the Rent List of Construction Machinery, Ministry of Construction, Japan, 1974 Edition.

d. Unit prices of heavy (regular) and light sheet piles in Japan were assumed at 58,000 ¥/ton and 62,000 ¥/ton respectively.

13. Problems in the Future.

In designing river training works in detail, some problems such as flow patterns, precise figuration and arrangement of hydraulic structures, precise scour

Table 4 - 4 Rough Estimation of Construction Costs

Site	Type	Guide bank (10^8Yen)	Closing dike (10^8Yen)	Subtotal		Transportation (10^8Yen)	Total	
				10^8 Yen	10^8 Taka		10^8 Yen	10^8 Taka
Bahadurabad	B	266	15	281	7.8	17	300	8.3
	C	231	3	234	6.5	16	250	6.9
Gabargaon	B	305	22	327	9.1	20	350	9.6
	C	262	5	267	7.4	17	280	7.9
Sirajganj	B	307	15	322	8.9	12	330	9.3
	C	278	-	278	7.7	12	290	8.0
Nagarbari	B	365	21	386	10.7	22	410	11.3
	C	321	-	321	8.9	12	330	9.3

around multi-column-type piers, etc. can not be solved by calculation alone. For the purpose of solving such problems in detail, hydraulic model tests will be a promising method.

Feasibility study may be completed without hydraulic model tests partly because feasibility study generally requires estimation of costs on the basis of basic designs and partly because the present feasibility study is limited to three years including the selection of the most suitable site from among the four proposed ones.

However, in making detail designs, if necessary, it can be considered to conduct some hydraulic model tests on a large scale and most carefully.

This type of bank structure needs a huge amount of stones and the construction was planned to be completed in two years in order to avoid losses of materials and works on condition that required quantity of stones is obtainable at specified stock yards and at any time specified. Therefore, supply of stones is an important problem to be solved in the near future. If sufficient supply of stones is impossible, the bank structure itself must be reconsidered or the plan of guide bank system may be abandoned according to circumstances.

Since a great number of construction machinery and a great amount of materials must be carried in within a short time, construction of large-scale cargo-handling facilities is necessary at the early stage of the whole construction period. These studies are not included in this report.

Fuel consumption by construction machinery was estimated to be about 200 kl per day at its maximum. Therefore, large-scale facilities for fuel supply are necessary on each side of the construction area.

Large-scale motor pools for maintenance and repairing of various construction machinery is needed on each side of the construction area. This is not included in the present report.

Since most of construction works are concentrated in the dry season and their amount of works is so huge, construction area is expected to be very crowded and complicated. Therefore, arrangement of construction machinery and management of personnel will be matters of importance and must be studied in detail at the stage of detail design.

ANNEX

BIBLIOGRAPHY AND DATA

All bibliography and data collected in Bangladesh and Japan and used in the present study are listed in this chapter. For the convenience of reference, they have been classified into the categories shown below.

WL : Data on water level.
DIS : Data on discharge.
RF : Data on rainfall.
FLD : Data on flood
SED : Data on sediment
BR : Data on boring test.
RC : Data on river course.
SVY : Data on surveying.
TOP : Topographic map.
PHT : Photograph.
CS : Data on construction cost.
PJT : Report on project concerning the Jamuna River.
GN : Data on general description of the Jamuna River.
ADM : Data on administration.
CF : Data on consulting firms.
MET : Data on meteorology.
CON : Data on construction works.
GB : General bibliography.
JB : Report on the Jamuna Bridge.
GE : Report on geography.
GM : Report on Geomorphology.

Seri. No.	Kind of Data	Bibliography or Data	Data Source
1	WL	BWDB WATER SUPPLY PAPER - 168 Gauge Readings of Brahmaputra-Jamuna River at Sirajganj, 1945 - 56	Surface Water, Hydrology Directorate, BWDB
2	WL,DIS	BWDB WATER SUPPLY PAPER - 2 Gauge & Discharge Observations for Ganges River at Hardinge Bridge, Paksey, 1933 - 58	"
3	WL,DIS	BWDB WATER SUPPLY PAPER - 18 Gauge & Discharge Records for B-J River at Bahadurabad, 1948 - 58	"
4	WL	BWDB WATER SUPPLY PAPER - 53 Gauge Readings of B-J River at Chilmari, 1957 - 58	"
5	WL	BWDB WATER SUPPLY PAPER - 55 Gauge Readings of B-J River at Chilmari, 1957 - 58	"
6	WL	BWDB WATER SUPPLY PAPER - 142 Gauge Readings of B-J River at Sirajganj, 1957 - 58	"
7	WL,DIS	BWDB WATER SUPPLY PAPER - 102 Gauge & Discharge Observations of B-J River, 1959 - 61	"
8	WL,DIS	BWDB WATER SUPPLY PAPER - 194 Gauge Readings & Discharge Observations of Ganges River, 1959 - 61	"
9	WL, DIS	BWDB WATER SUPPLY PAPER - 192 Gauge Readings & Discharge Observations of B-J River, 1962	"
10	WL	HYDROLOGICAL YEAR BOOK, 1964 - 65 Vol II : Water Levels	"
11	DIS	HYDROLOGICAL YEAR BOOK, 1964 - 65 vol III: Discharge	"
12	WL	HYDROLOGICAL YEAR BOOK, 1965 - 66 Vol II : Water levels	"
13	DIS	HYDROLOGICAL YEAR BOOK, 1965 - 66 Vol III: Discharge	Surface Water, BWDB
14	WL	HYDROLOGICAL YEAR BOOK, 1966 - 67 Vol II : Water Levels	"
15	DIS	HYDROLOGICAL YEAR BOOK, 1966 - 67 Vol III: Discharge	"
16	WL	HYDROLOGICAL YEAR BOOK, 1968 - 69 Vol II, Part-A : Water Levels	"
17	DIS	HYDROLOGICAL YEAR BOOK, 1968 - 69 Vol III: Discharge	"
18	ADM	Organization Chart of BWDB and River Morphology, Research and Training	River Morphology, Research and Training, BWDB

Seri No.	Kind of Data	Bibliography or Data	Data Source
19	GN	REPORT ON STUDY OF BANK MOVEMENT OF RIVER BRAHMAPUTRA by IECO, 1964	River Morphology, Research and Training, BWDB
20	FLD	BWDB WATER SUPPLY PAPER - 7 Technical Report on Flood in East Pakistan, 1960	Surface Water, Hydrology, BWDB
21	FLD	BWDB WATER SUPPLY PAPER - 223 Annual Report on Flood in Bangladesh for 1964	"
22	FLD	BWDB WATER SUPPLY PAPER - 251 Annual Report on Flood in East Pakistan for 1965	"
23	FLD	BWDB WATER SUPPLY PAPER - 272 Annual Report on Flood in East Pakistan for 1966	"
24	FLD	BWDB WATER SUPPLY PAPER - 308 Annual Report on Flood in East Pakistan for 1967	"
25	FLD	BWDB WATER SUPPLY PAPER - 355 Annual Report on Flood in Bangladesh for 1970	"
26	FLD	BWDB WATER SUPPLY PAPER - 357 Annual Report on Flood in Bangladesh for 1971	"
27	WL, DIS	BWDB WATER SUPPLY PAPER - 318 Water Level & Discharge Observation Records of Ganges River, Jan. 1963 - Mar. 1965	Surface Water, BWDB
28	SED	FAO-SF SECOND HYDROLOGICAL SURVEY IN BANGLADESH : Sediment Investigation, 1966 & 1967	"
29	SED	BWDB WATER SUPPLY PAPER - 359 Sediment Investigations in Main Rivers of Bangladesh, 1968 & 1969	"
30		Omitted	
31	GN	REPORT ON HYDROLOGY OF BANGLADESH By J. TH. THIJSSE, 1964	River Morphology, BWDB
32	PJT	DESIGN REPORT ON BANK PROTECTION STRUCTURE FOR THE PROTECTION OF SERAJGANJ TOWN FROM EROSION BY THE RIVER JAMUNA by Engineering Consultants, Inc. 1970	Western Zone, BWDB
33	PJT, CS	Serajganj Town Protection Project. •Plan : scale 16" = 1 mile •Weekly progress report for the week ending, 17 Aug. 1973	"
34	GN	WATER RESOURCES DEVELOPMENT AND FLOOD CONTROL IN BANGLADESH	Planning, BWDB
35	PJT	BRAHMAPUTRA LEFT EMBANKMENT by International Engineering Co. Inc., 1965	Planning, BWDB
36	PJT	BRAHMAPUTRA FLOOD EMBANKMENT PROJECT: Feasibility Report, Phulchari to Sirajganj; by International Engineering Co. Ltd., 1962	"

Seri. No.	Kind of Data	Bibliography or Data	Data Source
37	PJT	BRAHMAPUTRA FLOOD EMBANKMENT PROJECT: Definite Report by International Engineering Co., Ltd.	Planning, BWDB
38	PJT	BRAHMAPUTRA BARRAGE; Studies	"
39	PJT	FEASIBILITY REPORT FOR THE PROTECTION OF CHANDPUR TOWN: Vol. I Summary, Conclusion and Recommendations by Prokaushali Sangsad Limited	"
40	SED	MATERIAL TESTING REPORT: Report No. SED - 60, 1969	River Morphology, BWDB
41.	SED	SEDIMENT TESTING REPORT: Report No. SED - 68, 1970	"
42	SED	SEDIMENT PROBLEM STUDY: Note on Computation of Sediment Discharge and Bed-load, 1972	"
43	DIS	Discharge Observation by River Morphology: Dicharge Explanatory Notes Chilmari : 1965/66 - 1972/73 (1971/72; no data) Sirajganj : 1965/66 - 1972/73 Nagarbari : 1965/66 - 1971/72 Kalikapur : 1968/69 - 1972/73 Haripur : 1968/69 - 1972/73 (1971/72; no data) Jamalpur : 1968/69 - 1972/73 (1971/72; no data)	"
44	SED	Data on Sediment Discharge for 1970/71 at Nagarbari and Kalikapur	"
45	WL	Monthly Maximum Water Level of Regular Gages and Valley Gauges Since 1965	"
46	RC	Cross Section of the Brahmaputra River Within the Extent from Aricha to Bahadurabad for the Period from 1965 to 1973	"
47	RF	HYDROLOGICAL YEAR BOOK, 1964 - 65 Vol I: Rainfall & Evaporation	Surface Water, BWDB
48	RF	HYDROLOGICAL YEAR BOOK, 1965 - 66 Vol I: Rainfall & Evaporation	"
49	RF	HYDROLOGICAL YEAR BOOK, 1966 - 67 Vol I: Rainfall & Evaporation	"
50	RF	HYDROLOGICAL YEAR BOOK, 1967 - 68 Vol I: Rainfall & Evaporation	"
51	RF	HYDROLOGICAL YEAR BOOK, 1968 - 69 Vol I: Rainfall & Evaporation	"
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53	TOP	Irrigation Maps; scale = 1 : 40,000 No.79(E/9), 79(E/3), 78(H/9) - 78(H/16); 78(G/9) - 78(G/16)	River Morphology, BWDB
54	WL,DIS	Stage Discharge Relation of River Brahmaputra; Sirajganj : 1967/68, 1966/67 Chilmari : 1967/68	"

Seri. No.	Kind of Data	Bibliography or Data	Data Source
55	WL	Water Level Record of Regular and Valley Gauges for the Period from Apr. 1970 to Mar. 1971	River Morphology, BWDB
56	BR	Exploratory Drilling Logs; East West Interconnector Project	Ground Water, BWDB
57	BR	Exploratory Drilling Logs; 1000 Tube Well Project	"
58	CS	STATISTICAL DIGEST OF BANGLADESH No.7 : 1970 - 71	Bureau of Statistics Bangladesh
59	CS	Revised Estimates of Gross Domestic Product of Bangladesh for 1969/70 and 1972/73, Apr. 1973	"
60	CS	Price Index for 1972/73; •Wholesale Prices of Agricultual Products in Bangladesh Including Retail Prices of Some Selected Items •Cost of living : Dacca Middle Class •Consumer Price Index for Industrial Workers at Narayanganj •Wholesale Prices of Industrial Products of Some Selected Items	"
61	ADM	MANIFESTO OF BANGLADESH AWAMI LEAGUE	AWAMI LEAGUE
62	RC	Sounding Maps; scale 1 : 25,000 Nagarbari to Mirkutia via Char Pechokhole Sohagpur to Sirajganj Ghat, Sirajganj	IWTA
63	HDG	Data on Hardinge Bridge Typical Cross Section of Left Guide Bank Protection Works at Right Bank Left Guide Bank Showing Progress in Different Years Plan Showing Successive Alignment in Damukdia & Right Guide Bank in Connection with Closure of Gap	
64	HDG	Hardinge Bridge Section Taken at Center Line; from Jan. to Jun., 1968 from Jul. to Dec., 1968 from Jan. to Jun., 1969 from Jan. to Jun., 1970 from Jul. to Dec., 1970	
65	DIS,HDG	Discharge Measurements at the River Gauges at Hardinge Bridge from the Year 1968 to 1970	
66	HDG	HISTORY OF THE HARDINCE BRIDGE up to 1941	
67	HDG	RIVER TRAINING AND CONTROL by Francis J. E. Spring	
68	FLD	BWDB WATER SUPPLY PAPER - 67 Flood Report of East Pakistan, 1961	Surface Water, BWDB

Seri. No.	Kind of Data	Bibliography or Data	Data Source
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70	FLD	BWDB WATER SUPPLY PAPER - 182 Annual Report on Flood in Bangladesh for 1963	"
71	FLD	BWDB WATER SUPPLY PAPER - 330 Annual Report on Flood in East Pakistan for 1968	"
72	FLD	BWDB WATER SUPPLY PAPER - 357 Annual Report on Flood in Bangladesh for 1971	"
73	WL	HYDROLOGICAL YEAR BOOK, 1967-68 Vol II : Water Level	"
74	RF	Daily RAINFALL OF EAST PAKISTAN Jan. to Dec., 1960	"
75	RF	BWDB WATER SUPPLY PAPER - 170 Daily Rainfall of East Pakistan Jan. to Dec., 1961	"
76	RF	BWDB WATER SUPPLY PAPER - 227 Daily Rainfall of East Pakistan Jan. to Dec., 1962	"
77	RF	BWDB WATER SUPPLY PAPER - 226 Daily Rainfall of East Pakistan Jan. to Dec., 1963	"
78	GN	Line Diagram Showing Important River System ih Bangladesh	"
79	WL	Monthly Max & Min Water Level; Supplemental Data on Water Level of the Brahmaputra- Jamuna River and Ganges River	"
80	RPL	FEASIBILITY REPORT FOR THE PROTECTION OF CHANDPUR TOWN; Vol II Economic Investigation & Urban Planning	Planning, BWDB
81	RPL	FEASIBILITY REPORT FOR THE PROTECTION OF CHANDPUR TOWN; Vol III Engineering Aspects & Legislation	"
82	RPL	RESUME AND DESIGN Drawings for Chandpur Town Protection, Ist Phase	"
83	GN	RIVER AND FLOOD PROBLEMS OF BANGLADESH AND THEIR SOLUTIONS	Ministry of Flood Control and Water Resources
84	WL	HYDROLOGICAL YEAR BOOK, 1969 - 70 Vol II Part - A : Water Level	Surface Water, BWDB
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86	PJT,CS	FEASIBILITY REPORT FOR THE PROTECTION OF CHANDPUR TOWN; Vol IV Finacial Consideration & Project Evaluation	Planning, BWDB
87	GN	MASTER PLAN: Vol II by IECO	River Morphology, BWDB

Seri. No.	Kind of Data	Bibliography or Data	Data Source
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90	WL	Water Level Records of All Regular Gauges within the Extent from Aricha to Bahadurabad for the Period from 1st Sept. 1973 to 31st Oct. 1973	River Morphology, BWDB
91	PHT	Aerophotographs Covering the Jamuna River for 1952, 1963 and 1970 - 71, scale 1 : 50,000	Survey of Bangladesh
92	PHT	Aerophotographs Covering the Four Proposed Sites for 1970 - 71: scale nearly 1 : 10,000	"
93	TOP	Topographic Maps Covering the Jamuna River; scale 1:250,000, 1 : 50,000	Survey of Bangladesh
94	TOP	Topographic Maps Covering the Whole Country; scale 1:250,000, 1 : 50,000	"
95	PHT	Photographs of Right & Left Bank along the Jamuna River Taken from Helicopter at 1,000 m in altitude	River Study Team
96	BR	SOIL TESTING REPORT OF BRIDGE OVER RIVER BRAHMAPUTRA & JAMUNA, Miranpur (Bogra) Hole No. G4	Hydraulic Research Laboralory
97	SVY	Geodesic Triangulation Station	Survey of Bangladesh
98	GN	SEMINAR ON FLOOD CONTROL AND WATER RESOURCES DEVELOPMENT IN BANGLADESH, Aug. 1972	Ministay of Flood Control and Water Resources
99	PJT	DACCA SOUTH-WEST PROJECT : Feasibility Report Vol. IV Hydrology and River Hydraulics by ECI-ACE, Aug. 1970	
100	MET	Data on Meteorology for the Period from 1960 to 1972 at Rangpur, Bogra, Sirajganj and Faridpur	Meteorological and Geophysical Center in Chittagong
101	GN	Extract from SOME ASPECTS OF SEDIMENTOLOGY AND GEOLOGY OF BENGAL BASIN WITH SPECIAL REFERENCE TO THE BRAHMAPUTRA BASIN	Ground Water, Hydrology, BWDB
102	GN	Extract from RIVER OF THE BENGAL DELTA, by S. C. Majumder, 1941	"
103	GN,PJT	Extract from RIVER MECHANICS AND MORPHOLOGY, DACCA SOUTH-WEST PROJECT BANGLADESH, Reported by D. B. Simon & Others	"

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105	Br	Well Record Card; Kuchma X-1, Bogra X-1, Hazipur HX-1	"
106	ADM	PORT OF CHITTAGONG (Booklet), year book of information, 1972-73	Chittagong Port Trust
107	CS	Rental Rates of Schedule of Equipment MEO, BWDB	MEO, BWDB
108	CON	A SHORT NOTE ON DREDGING IN BANGLADESH, submitted by Adal Chief Engineer Services, BWDB	Dredger Organization BWDB
109	CS	BASIC DATA AND IDEAS ABOUT FUTURE DEVELOPMENT, Chittagon Steel Mill Ltd.	Chittagong Steel Mill Ltd.
110	SC	PRICE LIST, Chittagong Steel Mill Ltd.	"
111	CS	GENERAL ABSTRACT OF BUDGET OF SIRAJGANJ TOWN PROTECTION SCHEME UNDER BORGA W.D. CIRCLE FOR THE YEAR 1973-74	Brahmaputra Survey Division BWDB
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CHAPTER V

STUDY OF BRIDGE WORKS

1. General Consideration.

(1) Reconnaissances at Bangladesh.

The Bridge Planning Team carried out some reconnaissances, collection of data necessary for planning and design of bridge and some confirmation and discussion with the Bangladesh government authorities concerned from 8th Jan. to 1st Feb. in 1974 in Bangladesh.

These data were reviewed and studied, and used as the base of this report.

The contents of data collected during the reconnaissance at the bridge site are found in ANNEX-1.

As for the general design specifications of railway and highway bridge, a meeting was held between the Japanese Feasibility Study Team and the delegates of the Government of Bangladesh, and general items were agreed between both the parties as follows.

Details of design specifications will be stated in Section 2, Design Conditions and Standard.

a. Live Load.

Live load to be used for design of railway bridge will be specified by Main Line Loading of Bridge Code for Indian Railways.
Live load for highway bridge will be specified by the I.R.C. Standard Vehicle Class A.

b. Track Gage.

The track gage for design shall be 5'6" (Broad gage).

c. Navigation Clearance.

The minimum navigation clearance to be used for design is specified by BIWTA as follows.

Minimum horizontal clearance .... 250 feet.
Minimum vertical clearance .... 40 feet.

(2) Proposed sites of bridge.

The Preliminary Survey Team has proposed the following four sites for bridge crossing.

Site - 1 Bahadurabad

Site - 2 Gabargaon

Site - 3 Sirajganj

Site - 4 Nagarbari

At the first stage of this study, the study team shall compare the four proposed sites for bridge construction and decide the most suitable site in accordance with the three criteria mentioned in the Inception Report.

(3) Selection of bridge types from the aspect of transportation system.

The following types of bridge can be considered.

a. Highway bridge.

b. Railway bridge.

c. Railway-cum-highway bridge.

The transport network in the People's Republic of Bangladesh consists of railway transport, highway transport, inland water transport and air-route transport, among which railway and inland water transport are most important.

Above all, railway transport occupies a greater part of overland transportation in Bangladesh.

It can be said that railway transport plays the most important role in the overland transportation socially and economically.

Therefore, when bridge across the Jamuna River will be planned, it is clear that railway bridge takes precedence of highway bridge. But according to the recent study for land transportation in Bangladesh, highway transportation is increasing gradually by the strengthening of capacity of road ferry. Such transport tendency can not be disregarded. It is natural that the highway bridge across the Jamuna River is also necessary for the improvement of future highway network in Bangladesh.

There are two ways to be considered in order to meet such transport demand. One is to construct highway bridge and railway bridge separately and the other is to construct railway-cum-highway bridge. The construct railway-cum-highway bridge across the Jamuna River. The former will be expected larger benefit than the latter but higher total cost of construction will be needed.

We judged that it is the best way to construct railway-cum-highway bridge considering future transport network and economic development of Bangladesh.

Therefore the assumed type of bridge which is selected at the most suitable site shall be the railway-cum-highway bridge.

According to the Feasibility Report performed by Freeman, Fox and Partners (stage 1), it is reported that the estimated benefit-cost ratio of railway-cum-highway bridge will be about double of that of highway bridge.

(4) Width of bridge.

The determination of effective width of the Jamuna Bridge is one of the most important matter for this Project, because it depends largely upon not only future overland transport in Bangladesh but also total cost of construction.

There are two ways of thinking in order to determine an effective width of the Jamuna bridge. One way is to determine the effective width of bridge so as to minimize the total cost of construction of the bridge. This will be done by giving the least necessary width to the bridge considering future increase of traffic volume.

The other way is to determine the effective width of bridge taking future increase of traffic volume through the bridge and also future economical development of Bangladesh into consideration. In this case, higher cost of construction will be needed than previous case but is desirable for the future development of Bangladesh.

Taking above-mentioned two ways of thinking into consideration, we carried out the study of following two cases.

Case a.

Railway part:	Single broad gauge track (5ft 6in)
Highway part:	Two-lanes carriageway of total width 24ft.

Case b.

Railway part: Double broad gauge track

Highway part: Four-lanes carriageway of total width 48ft.

In case b, so far as traffic conditions permit, it is possible to introduce a method of stage construction, namely, at first, construct a bridge with least necessary width and afterwards, residual width is added in accordance with an increase of traffic volume through the bridge.

The standard cross section of above-mentioned two cases are shown in Fig. 5-1.

(5) Scopes of works for bridge planning.

The proposed bridge were classified into the next two scopes.

a. Main bridge over the Jamuna River

Main bridge over the Jamuna River and banking, viaduct included in approach road.

b. Bridges included in link parts

Railway bridge included in the rail links and Road bridge included in the road links.

Above-mentioned classifications and definitions shall be shown in Fig. 5-2.

(6) Preliminary selection of bridge type.

1) Main bridge over the Jamuna River.

Choice of type for bridge may be considered from the following three aspects.

Selection of materials.

Selection of types of superstructure.

Selection of types of substructure.

a. Selection of materials for superstructure.

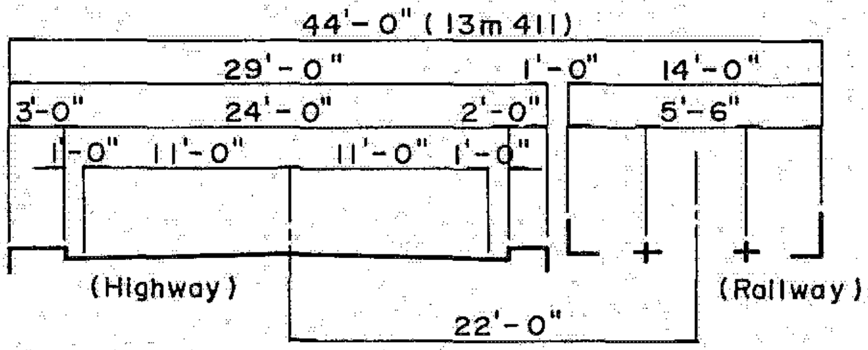
It is clear that total length of bridge is determined by the width of necessary waterway between left and right guide banks.

The each clear span of the bridge will be determined by the width of navigation channel which are specified by the BIWTA, that is 250 ft.

Considering above conditions, steel and concrete (prestressed concrete) are recommended as for the construction materials.

Fig 5-1 STRUCTURAL WIDTH OF BRIDGE

a) In case of two lanes , single track.



b) In case of foure lanes , double track
(for double decks)

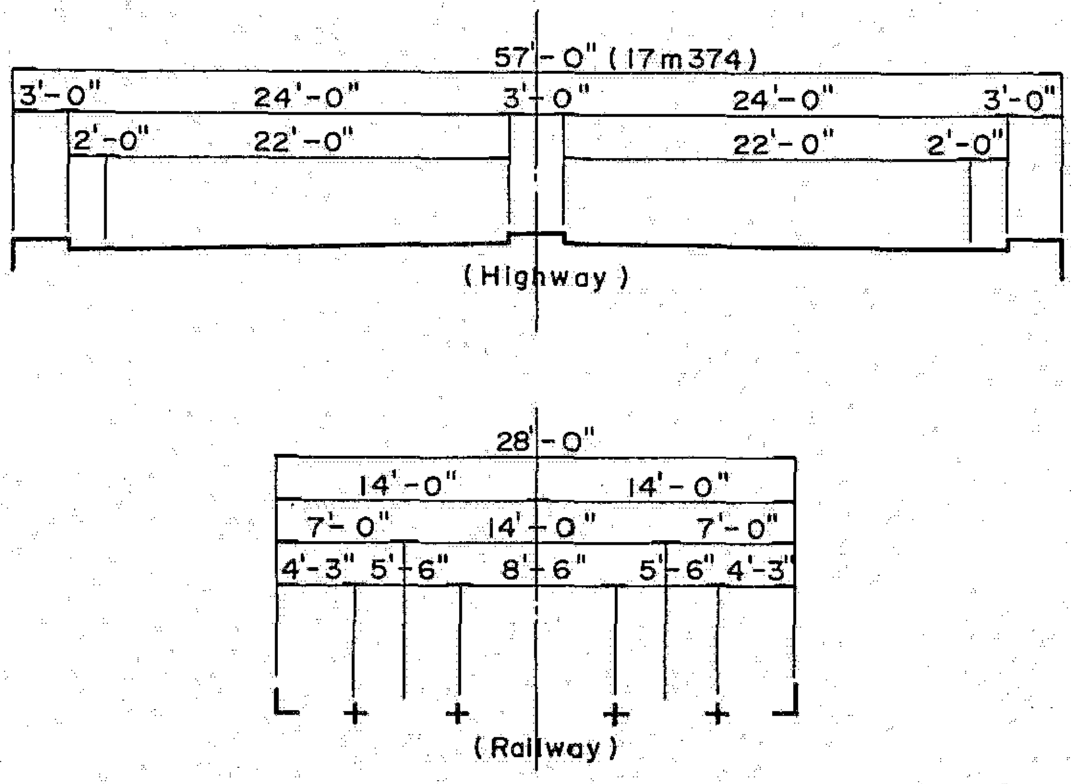
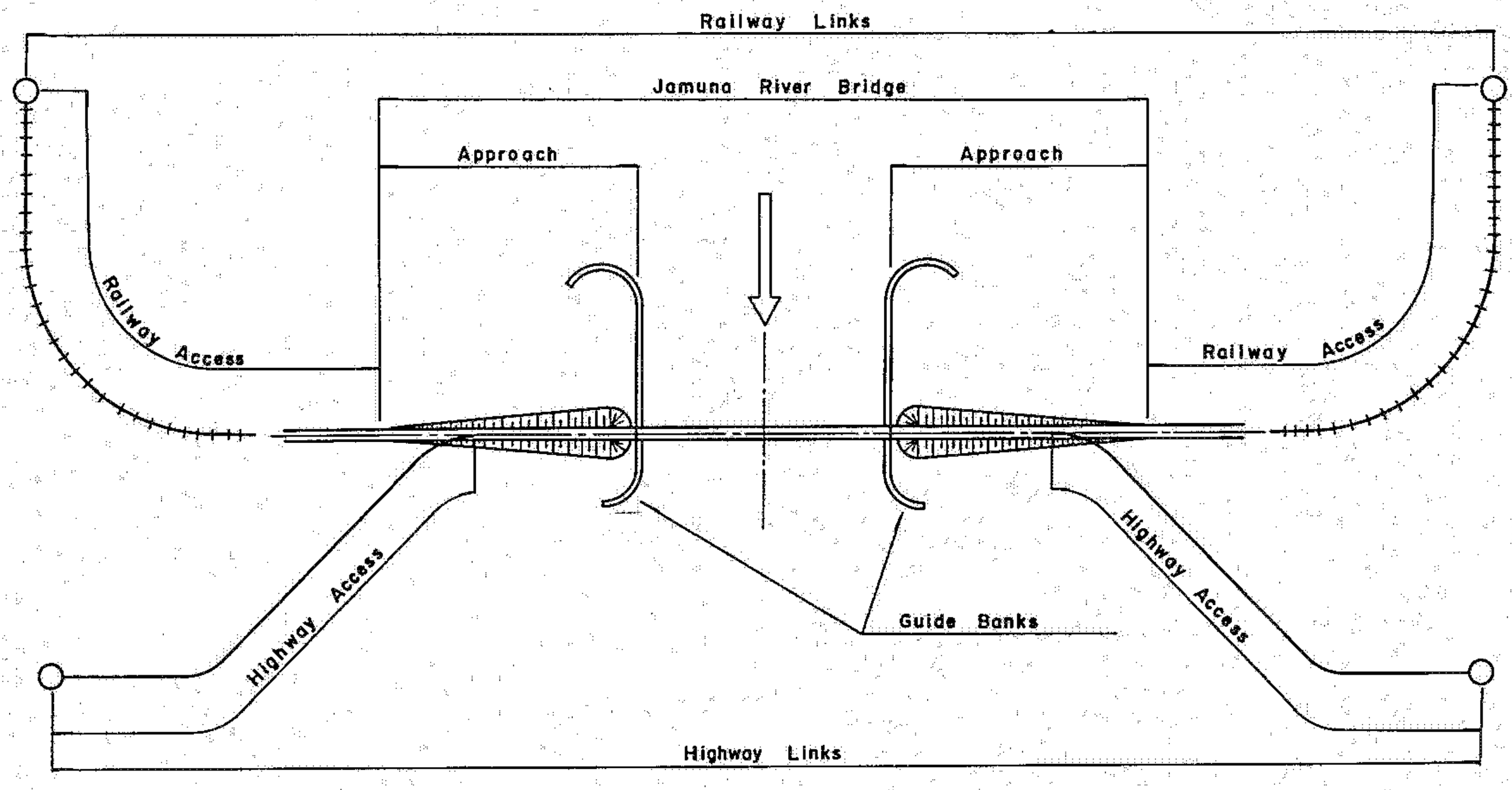


Fig. 5 - 2 Descriptive Figure of The Study.



The merits of steel bridge as compared with prestressed concrete bridge are as follows.

i. The weight of steel bridge (hereinafter called SB) is lighter than that of prestressed concrete bridge (hereinafter called PB), therefore the inertia force of SB due to earthquake acted to substructure of the bridge is smaller than that of PB when the supported length is equal. This means that the cost saving of substructure can be expected.

ii. SB is more practicable and advantageous to apply to longer span than PB.

Erection of SB is easier and faster than that of PB, so it is possible to cut the period of construction work.

iii. When the multipile foundation system is applied to the substructure, such system will be deflected horizontally by current pressure.

Effect of horizontal displacement of bridge shoe due to such deflection can be easily treated in the case of SB.

The demerits of SB are as follows.

i. Higher cost of maintenance will be needed. (for example, cost of repainting etc.)

ii. Possibility of application of domestic materials will be limited.

Considering above-mentioned merits and demerits, we concluded that steel bridge is more practicable than prestressed concrete bridge in the case of the Jamuna River Bridge.

b. Selection of Structural Types of Main Girder

It is clear that very deep foundation is needed for the Jamuna River Bridge and its cost is high. This means that the proportion of cost of substructure to total construction cost of bridge is high. In order to minimize the total construction cost of bridge, it is expected that the structural types of bridge should be selected among various types of bridge applicable to long span.

As is generally known, cantilever truss type and/or continuous truss type is suitable for long span.

Therefore, now we are carrying out bridge planning work taking three equal span continuous truss (length of each span is 330 ft and 500 ft) and three equal span cantilever truss (length of each span is 820 ft and 1150 ft) into consideration.

c. Substructure.

The Jamuna River is braided river, so even if the guide bank system is applied for the river training in order to fix the river channel, the deepest part of river channel will fluctuate to and fro in the river channel. Therefore, it is requested that foundation of all piers should have equal depth.

According to the result of our test boring, reliable gravel layer exists several ten meters below ground level at every four proposed sites.

This means that the deep foundation will be needed for every pier of the bridge.

Accordingly, in order to determine a composition of span, it is necessary not only to consider harmony and simplicity of structure but also to reduce the total cost of construction as much as possible.

Because of the necessity of very deep foundation, well and multipile foundation were assumed as the types of substructure in consideration of simplicity of execution. Well foundations are frequently applied in Bangladesh, but in this type, though there will be no primary difficulties, very large scale work should be necessary because it is requested to sink the well about 230-300 ft. under the high water level.

In the case of multipile foundation systems, it is necessary to drive in large steel piles in the bearing layer and to connect with heads of these steel piles rigidly above the water level.

This type is superior in execution than the former, but may be more flexible due to its structural mechanism, and in the case of pile foundation as mentioned above, local scouring around the pier is comparatively less than in the case of well foundation.

d. Approaches.

It is the cheapest way to connect a bridge with access railway by embankment provided that the bearing power of ground under such an embankment is to resist enough to the weight of embankment.

If these conditions should not be satisfied, many short span bridges for railway approach should be requested. But these details will be studied in the 2nd stage of this project.

This embankment crosses the guide banks at right angle each other and the embankment with a length of about 2.5 mile will be needed provided that the allowable maximum longitudinal slope of railway is 1/200. This length of embankment is also required from the river training view point and the alignment of embankment is preferable to be a straight line.

The center line of highway approach must be shifted from the center line of railway approach in the case b in order to connect the carriage way of bridge with the carriage way of access road.

As the level of carriage way of bridge is comparatively high and the center line of highway approach consists of curved part, it is easier to construct a steel bridge than to construct a reinforced or prestressed concrete bridge. Therefore we selected a steel bridge at the first stage of this project. Comparison of reinforced or prestressed concrete bridge with steel one will be performed at the second stage of this project in accordance with necessity.

These viaduct shall be supported by pile foundation.

2) Access parts.

The bridges of span over 300 ft included in the domain of railway access or highway access part are shown in Table 5-1 and 5-2 with the data of names of rivers, total bridge length and minimum navigation clearance in each proposed route respectively.

Navigation clearances are generally shown in the map of BIWTA. Besides these data, 12 ft in min. vertical clearance and 100 ft in min. horizontal one are necessary as the navigation clearance in the Bangali River, Karatoya River (upstream of Bogra city) and Chatal River.

Navigation clearances about the other rivers were assumed by reference to the scale and capacity of rivers and navigation clearance of the existing bridges.

These clearance of bridges included in the domain of the proposed railway or highway excess parts, must be ascertained at the second stage of

Table.5-1 Data of Bridges (longer than 330 ft.) in the Domain of Railway Access

No. of Site	Right Side of River-Bank					Left Side of River-Bank					Numbers of Bridges
	Location (mile)	Name of the River	Total Bridge Length (ft)	Min. Horizontal Clearance (ft)	Min. Vertical Clearance (ft)	Location (mile)	Name of the River	Total Bridge Length (ft)	Min. Horizontal Clearance (ft)	Min. Vertical Clearance (ft)	
1	4.8	Bangali	980	100	12	—	—	—	—	—	2
	7.8	"	660	100	12	—	—	—	—	—	
2	0.6	Karatoya	330	100	12	30.2	Chatal	1 310	180	25	7
	5.5	Hurasagar	330	100	12	30.7		490	60	6	
	11.6	Bangari	490	100	12	31.5		490	60	6	
	13.2		330	100	12	—	—	—	—	—	
3	—	—	—	—	—	27.8	Lohatang	330	60	6	6
	—	—	—	—	—	34.2	Futjani	660	60	6	
	—	—	—	—	—	42.5	Bansi	330	60	6	
	—	—	—	—	—	49.1		660	100	12	
	—	—	—	—	—	60.0	Turag	980	100	12	
	—	—	—	—	—	68.5	Tungi	980	100	12	
4	9.2	Chikunai	330	60	6	35.9	Old Dhaleswari	660	60	6	9
	9.6	Rukunai	660	60	6	42.9	Dhaleswari	3 770	180	25	
	19.2	Baral	1 970	60	6	48.3		330	60	6	
	20.4	Hurasagar	980	180	25	62.1	Bansi	820	150	20	
	—	—	—	—	—	70.6	Turag	490	150	20	

Table.5-2 Data of Bridges in the Domain of Highway Access.

No. of Site	Right Side of River Bank					Left Side of River Bank					Numbers of Bridges
	Location (km)	Name of the River	Bridge Length(ft.)	Min. Horizontal Clearance (ft.)	Min. Vertical Clearance(ft.)	Location (km)	Name of the River	Bridge Length(ft.)	Min. Horizontal Clearance (ft.)	Min. Vertical Clearance(ft.)	
1		Bangali	980	100	12		——	330	100	12	3
		Bangali	660	100	12		——	——	——	—	
2		Karatoya	330	100	12		——	330	60	6	5
		Bangali	980	100	12		Chatal	1 310	180	25	
		——	——	——	—		——	330	60	6	
3											
4		Hurasagar	1 970	180	25		Old Dhaleswari	660	60	6	4
		——	980	60	6			330	60	6	

Note

this project.

Bridges in access part have medium spans in design, so reinforced or prestressed concrete bridges are preferable as construction system in this domain in order to be available for the application of domestic materials and to give a chance to the local constructors. In this case, reinforced concrete or prestressed concrete bridge will be cheeper than steel bridge.

2. Design Conditions and Standards.

(1) Guide bank.

Distance between guide banks in Chapter IV "Study of River Training Works" is shown in Fig. 5-3 at the four proposed sites respectively.

(2) Design high water level, river bed height and ground height.

The part where the center line of bridge crosses a guide bank is called the body of guide bank and Design High Water Level (D.H.W.L.), River Bed (R.B.) and Ground Height (G.H.) for the cross section of river along the center line of bridge are shown as in Table 5-3-1.

In this table, height of river bed means height of the deepest part of river bed.

(3) Local scouring around piers.

Depth of local scouring around piers is estimated about 1.8 times of water depth. But in this case, it is assumed that width of foundation which is measured perpendicular to the direction of flow is 33-39 ft., this case implies a well foundation.

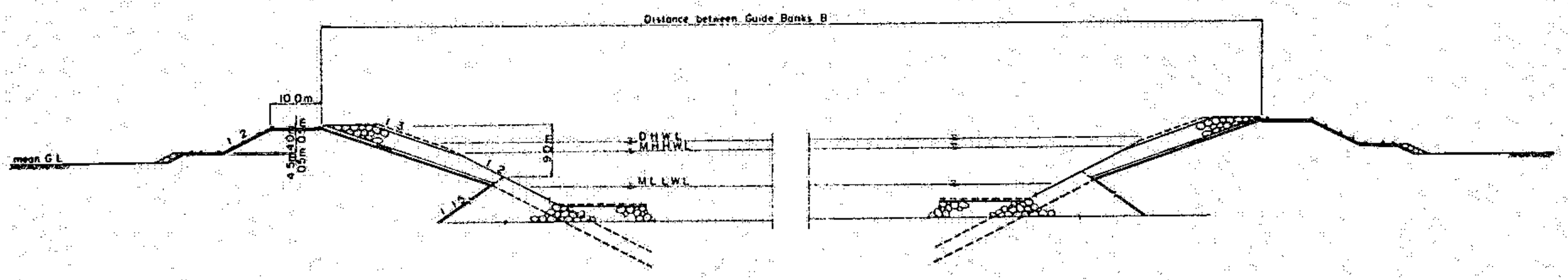
In the case of multi-pile system when diameter of each pile is 6 - 10 ft. the estimation of depth of local scouring around piers is estimated 33 ft. and in this case, necessary distance between center to center of pile is 3 times of diameter of pile.

The estimated depth of local scouring around piers in the case of A, B and C type (width of water channel) at the four proposed sites are shown in Figs. 5-4-1 ~ 5-4-4 with soil maps "Design river bed and soil map".

(4) Design discharge and velocity.

The design discharge Q (m^3/sec), the mean velocity Vm (m/sec) and the mean velocity at the deepest part of river channel V (m/sec) at the

Fig.5-3 Distance between Guide Banks



KM (MILE)

SITE \ TYPE	A	B	C
1. BAHADURABAD	2.0 (1.2)	4.2 (2.6)	5.6 (3.5)
2. GABARGAON	2.0 (1.2)	4.2 (2.6)	5.2 (3.2)
3. SIRAJGANJ	2.0 (1.2)	4.2 (2.6)	5.6 (3.5)
4. NAGRBARI	2.0 (1.2)	4.2 (2.6)	5.2 (3.2)

Table. 5-3-1 D.H.W.L., R.B and G.H

(m) PWD

Site \ Item	D.H.W.L.	R B			G H
		A	B	C	
1. Bahadurabad	20.86	− 29.68	− 16.82	− 10.37	17.95
2. Gabargaon	19.44	− 35.45	− 21.60	− 16.11	15.73
3. Sirajganj	15.24	− 38.60	− 25.50	− 18.20	11.38
4. Nagarbari	14.01	− 42.13	− 28.37	− 22.82	9.45

Table. 5-3-2 Q, Vm and V

Site	Type \ Item	Q (m^3/s)	Vm (m/s)	V (m/s)
1. Bahadurabad	A	89 600	2.40	4.66
	B	〃	1.93	4.35
	C	〃	1.74	3.94
2. Gabargaon	A	89 600	2.21	4.29
	B	〃	1.77	4.00
	C	〃	1.65	3.73
3. Sirajganj	A	89 600	2.25	4.36
	B	〃	1.78	4.03
	C	〃	1.63	3.68
4. Nagarbari	A	82 700	1.99	3.87
	B	〃	1.58	3.57
	C	〃	1.47	3.32

Note; $1^{km} = 0.621^{mile}$ $1^{m} = 3.28^{feet}$ $1^{m^3} = 35.3^{cu.feet}$

four proposed sites are shown in Table 5-3-2 considering in the case of A, B and C type.

3. Soil Texture.

According to the result of boring at the every proposed sites, the upper layer is silty and fine sand (Au_2) and in the lower layers, fine to medium sand (Au_1), med. sand (Am_3), dense fine to med. sand ($Am_{2,1}$) are found from top to bottom in turn.

The layers beneath Am_3 are over 60 of N-value by the standard penetration test and are considered as the reliable bearing layer. Under Am_3 layer at Nagarbari and Sirajganj, gravel and boulder layer (Al_1) of about 23-30 ft. in thickness is found out about 300 ft. and 240 ft. below ground level respectively.

At Gabargaon and Bahadurabad, coarse sand with small gravels (Du_2) is found out about 190 ft. and 180 ft. below ground level respectively.

The soil textures at the every four proposed sites are shown in Figs. 5-4-1 ~ 5-4-4 with proposed height of river bed.

(6) Design river bed height and soil map.

Soil map, and design bed height, depth of local scouring around piers, design high water level, low water level and mean ground height are shown in Fig. 5-4-1 ~ Fig. 5-4-4 at the four proposed sites respectively according to the height in accordance with the A, B and C type. All height is shown referring to the bench mark of PWD.

(7) Superstructures.

1) Railway bridge.

a. Loads. (ANNEX 2)

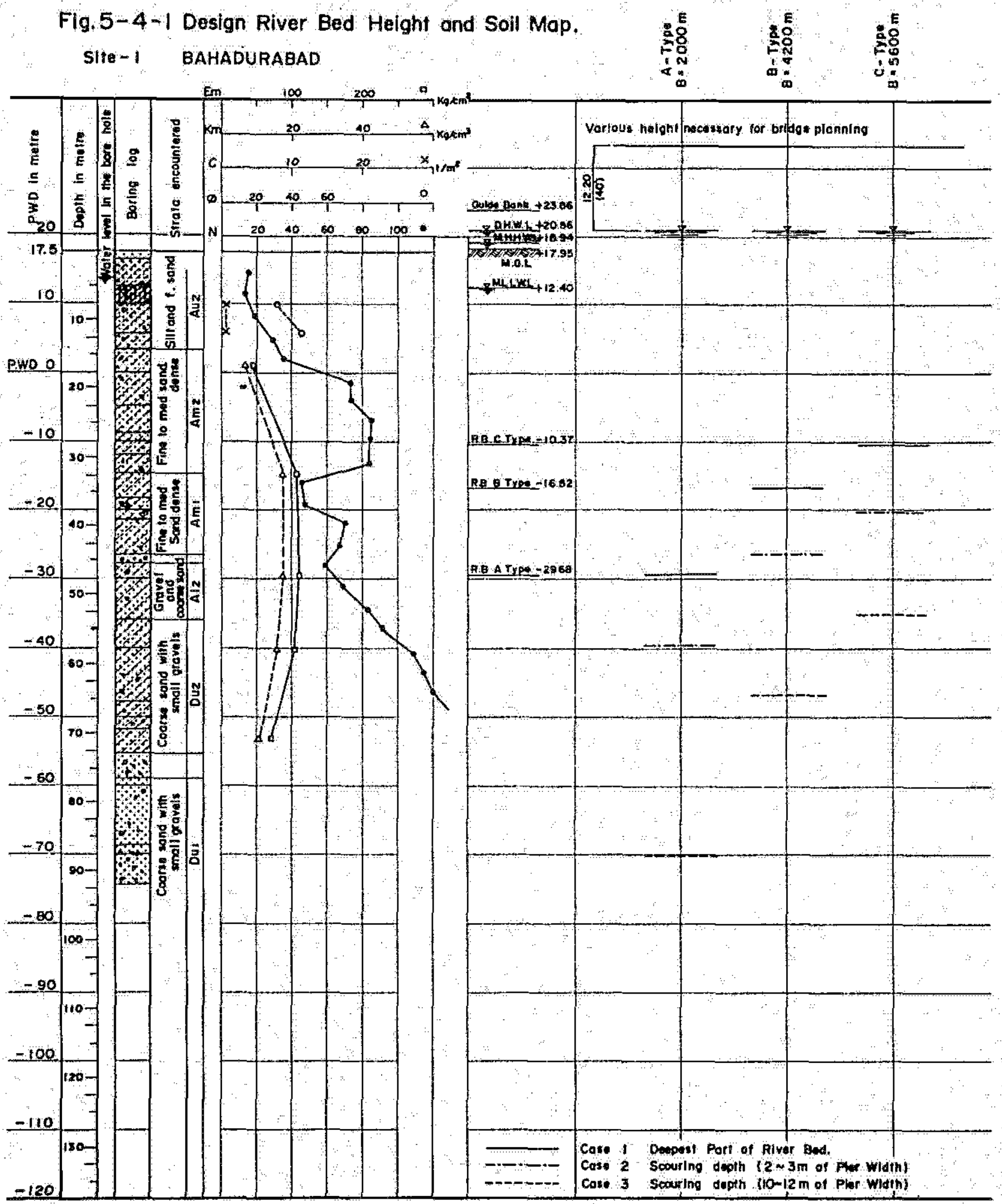
All loads to be used for design will be specified by Main Line Loading of Bridge Code for Indian Railways.

b. Construction gage. (ANNEX 2)

The construction gage will be specified by the Bridge Code for Indian Railway keeping the provision of electrification in future.

Fig. 5-4-1 Design River Bed Height and Soil Map.

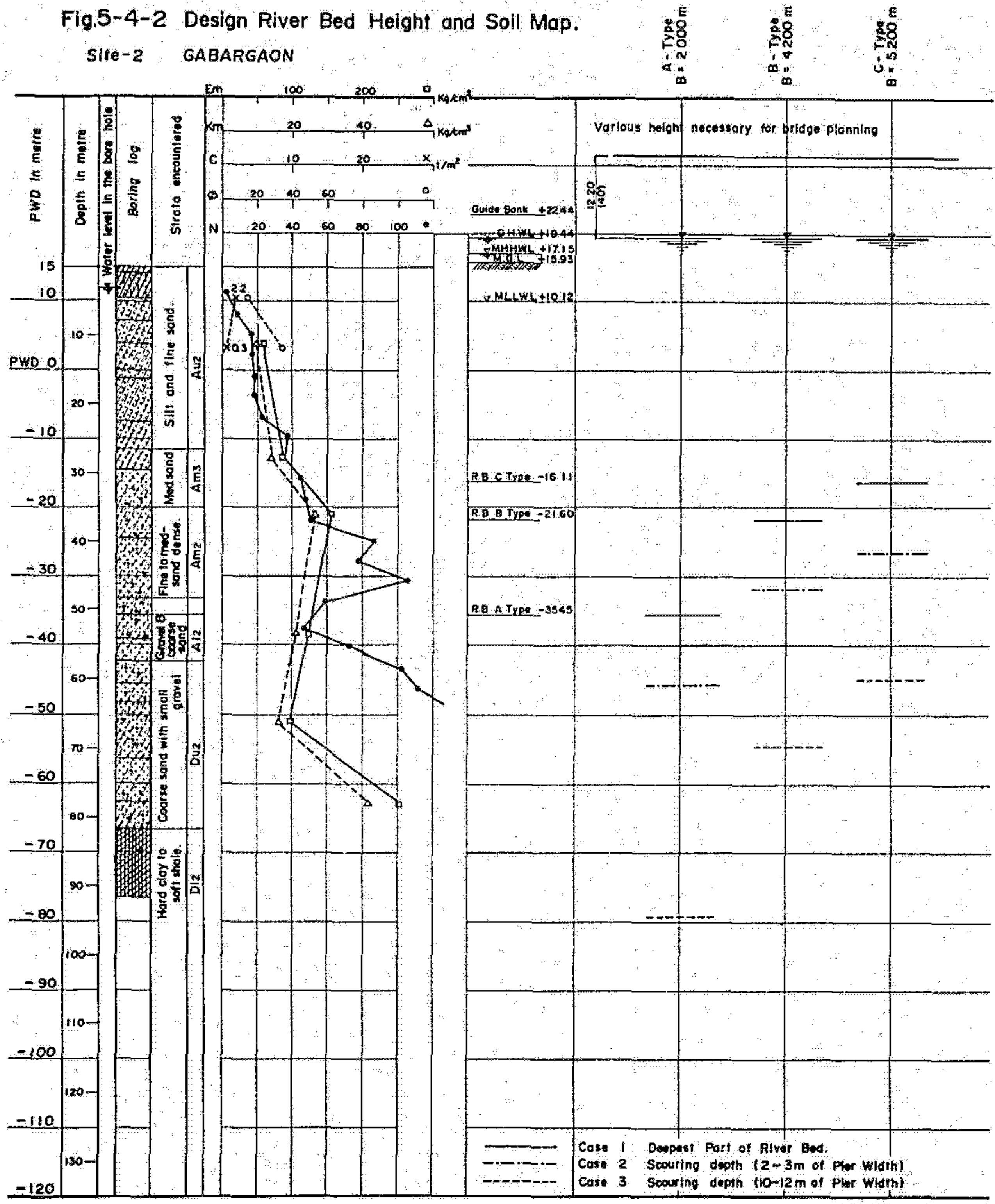
Site - I BAHADURABAD



Note. B; Distance between guide bank
E; Modulus of deformation
K; Modulus of foundation
C; Cohesion
Ø; Internal friction angle
N; Values of standard penetration tests

Fig.5-4-2 Design River Bed Height and Soil Map.

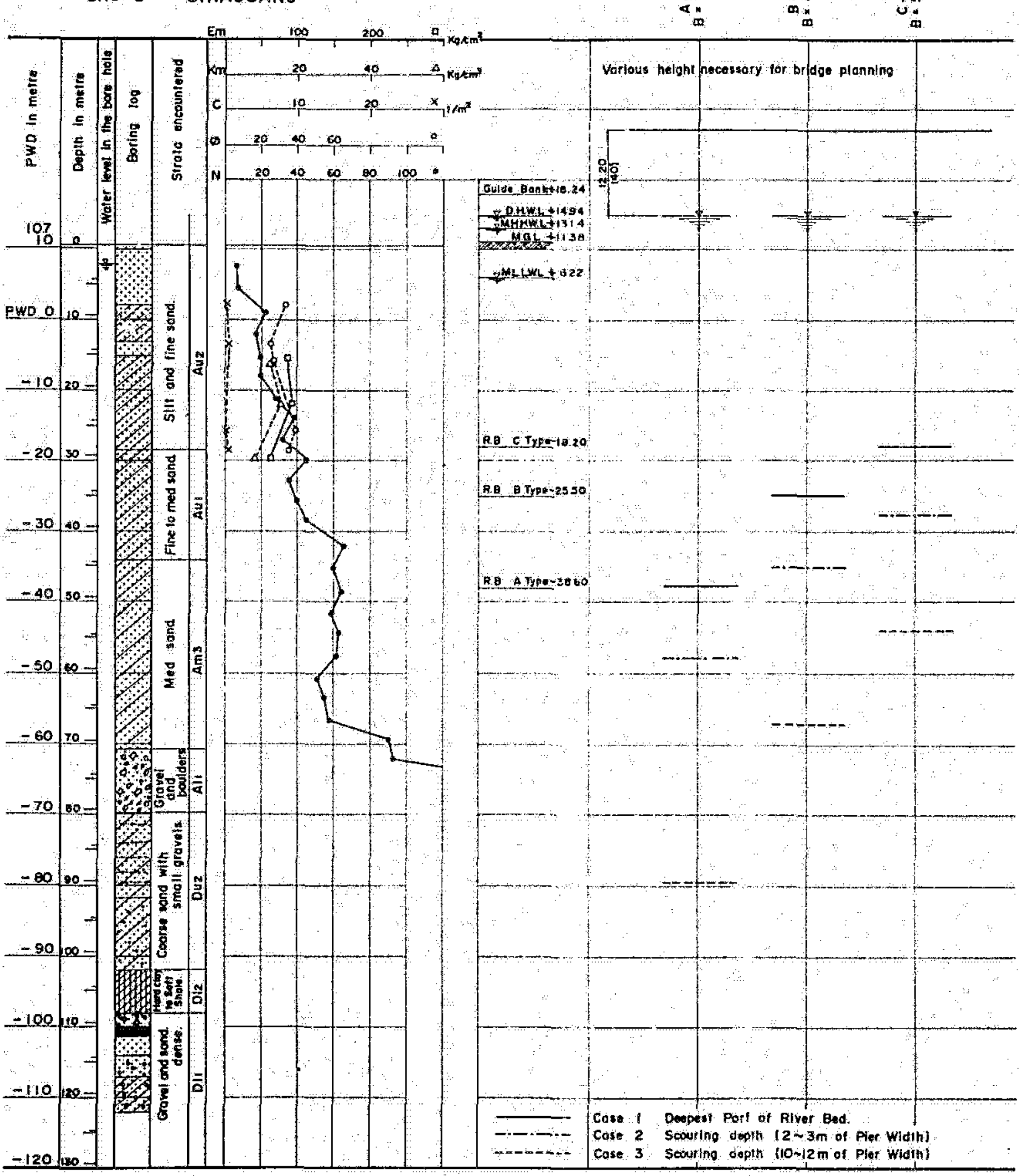
Site-2 GABARGAON



Note. B; Distance between guide bank
E; Modulus of deformation
K; Modulus of foundation
C; Cohesion
Ø; Internal friction angle
N; Values of standard penetration tests

Fig.5-4-3 Design River Bed Height and Soil Map.

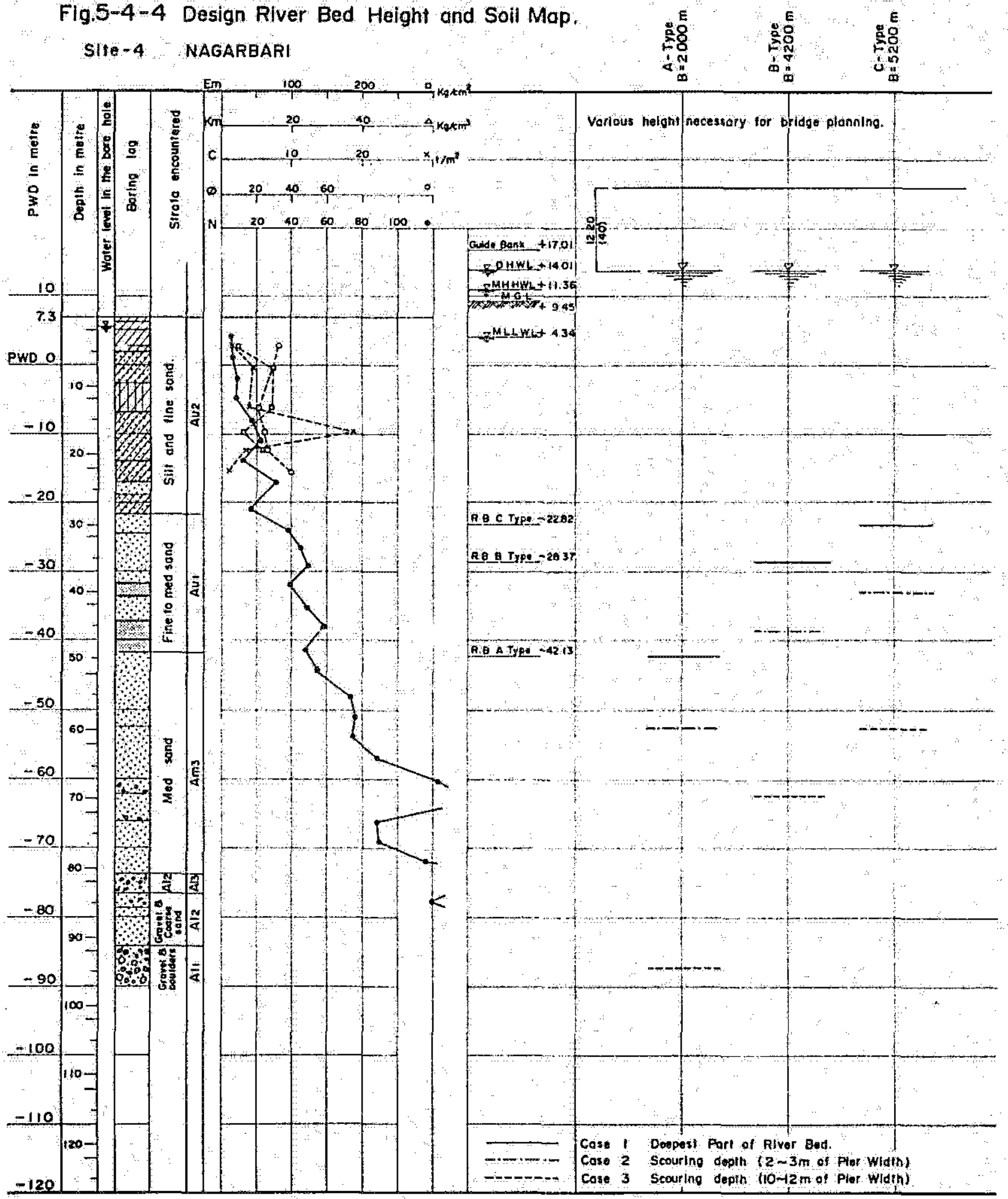
Site-3 SIRAJGANJ



Note. B; Distance between guide bank
E; Modulus of deformation
K; Modulus of foundation
C; Cohesion
Φ; Internal friction angle
N; Values of standard penetration tests

Fig.5-4-4 Design River Bed Height and Soil Map.

Site-4 NAGARBARI



Note. B; Distance between guide bank
E; Modulus of deformation
K; Modulus of foundation
C; Cohesion
φ; Internal friction angle
N; Values of standard penetration tests

c. Track gage.

The track gauge to be used for design shall be 5' 6" (Broad gage)

d. Structures.

All structures will be designed by the Standard Specifications for Railway Bridges adopted by the Japan Society of Civil Engineers (authorized by the Government Railway of Japan), except the following matters which were determined by the Team considering local conditions of Bangladesh.

i. Wind velocity.

The wind velocity which makes the basis of calculation of wind pressure to be used for design is 35 m/sec.(115ft./sec)

ii. Range of temperature.

The range of atmospheric temperature to be used for design is from 0^{o} to $40^{o}C$.

iii. Horizontal acceleration of earthquake.

The horizontal acceleration of earthquake which makes the basis of calculation of horizontal inertia force to be used for design is 0.1 G.

e. Materials.

All materials to be used for design will be specified by the Japanese Industrial Standard.

2) Highway bridge.

a. Loads.

Live load to be used for design will be specified by the I.R.C. Standard Vehicle Class A.

b. Construction gage.

The construction gauge will be specified by I.R.C.

c. Structures.

All structures will be designed by the Standard Specifications for Highway Bridges adopted by the Japan Road Association (authorized by the Ministry of Construction of Japan), except the following matters which were determined by the Team considering local conditions of Bangladesh.

i. Wind velocity.
ii. Range of temperature.
iii. Horizontal acceleration of earthquake.
These are just same as railway bridge.

d. Materials.

Same as above.

(8) Substructures.

According the result of meeting between both the parties, the following specifications will be applied for the design of substructures.

Standard Specifications for Reinforced Concrete adopted by the Japan Society of Civil Engineers (authorized by the Ministry of Construction of Japan).

(9) Minimum navigation clearance. (ANNEX 3)

The minimum navigation clearance to be used for design is specified by the BIWTA as following.

Minimum Horizontal Clearance.

Between adjacent piers 250 feet.

Minimum Vertical Clearance.

Under soffit of the girders 40 feet.

3. Comparison and Study of The Jamuna River Bridge.

(1) General.

As above-mentioned, distances between guide banks are 2.0 km, 4.2 km and 5.2 ~ 5.6 km at the four proposed bridge sites respectively and each guide banks have three types. By reason mentioned in Chapter IV distance between guide banks should not be narrowed than about 4 km, so the case under 2 km in width was excepted in the study of the Jamuna Bridge Project.

Therefore distances between guide banks are two types at each side.

In superstructure, metal truss type was adopted and span length of 328 ft, 492 ft, and 1148 ft were considered taking the minimum navigation clearance in horizontal direction into consideration, and well foundations were adopted for substructure.

Two types of well foundation and multi-pile-foundation were considered in substructure. In the study of the Jamuna Project we studied about these combinations in view of minimum cost.

(2) Superstructure.

1) Type of structure.

As above-mentioned, proposed span length of this bridge is in an extent of 300 ft~1200 ft. Bridge types generally considered applicable to this kind of span are shown in Table 5-4.

They are suspension bridge, cantilever truss bridge, continuous truss bridge, tied arch bridge, cable-stayed bridge, etc. Based on the data and information of these type of bridge, various factors were studied from the view points of economy, mechanical reasonability, and safety and comfortableness for vehicle traveling. Since the bridge is to be designed for a double purpose, railway-cum-highway, a bridge type with sufficient stiffness is required to cope with the heavy train load. Furthermore such a width system implies a bridge type which can accomodate itself to the double deck. As a result of these studies, it was judged that the truss type is the most desirable for this bridge. Moreover, on the assumption that the steel structure of bridge itself is to be shipped, shipping cost of truss bridge in comparison with other would be lower than other type of bridge because of its smaller measurement tonnage. These are chief reasons of selection for truss type bridges.

Based on the above described reasons and taking the dispersion of horizontal forces against substructure into consideration, three-span continuous truss bridge for the spans 328 ft and 492 ft and multi-span cantilever truss bridge for the spans 820 ft and 1148 ft were considered. According to general practice and trial computations, truss with curved chord is more reasonable than parallel one and, therefore, frame of truss was determined as shown in Table 5-5 below.

2) Outline of structure.

Cross section of each truss members is box shaped and I-shape cross section was chosen for stringes and floor beams.

Fabrication of these members in the shop yard shall be done by electric

Table. 5-4 Suitable Bridge Types by Different Span Length.

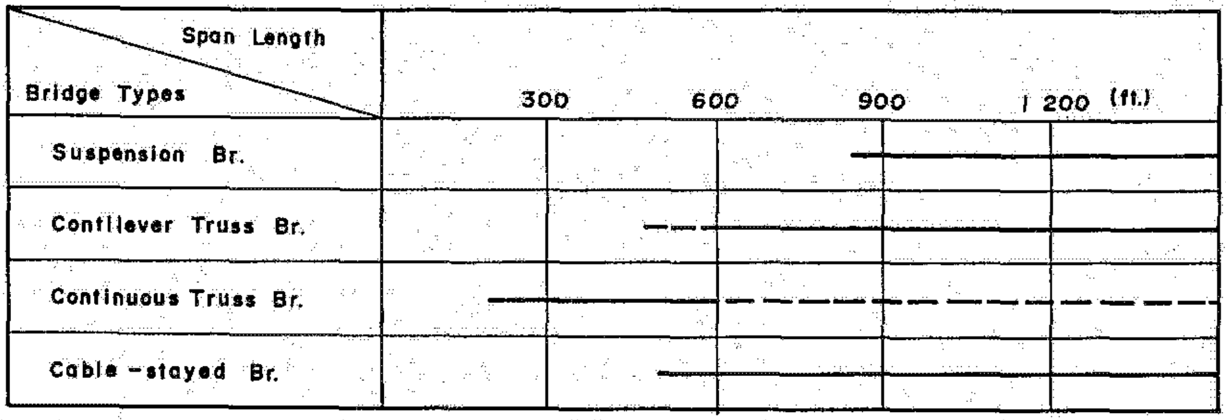
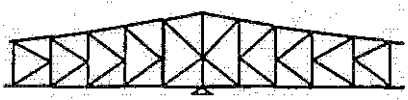


Table. 5-5 Frame of Truss

Span Length	
328'- 1" 492'- 1½"	
820' - 2½" 1 148' - 3½"	

arc welding. High tensile bolts shall be used for splices and connection of these members at the job site. Two types of floor slab that is reinforced concrete slab and orthotropic steel deck were considered.

Reinforced concrete slab was adopted for the spans shorter than 492 ft and orthotropic steel deck was considered for the spans longer than 492 ft. The reason is that to use reinforced concrete slab for a long span would increase the dead load remarkably and thereby cause an unfavorable condition to the superstructure as well as substructure. Railway bridge was designed with open floor.

3) Material requirements.

In consequence of the intermediate design of the superstructure of this bridge, total steel weight and volume of reinforced concrete member were shown in Table 5-6 for two kinds of system of width and four kinds of span length.

Total steel weight and volume of reinforced concrete for the total length of the bridge were shown in Table 5-7.

(3) Substructure.

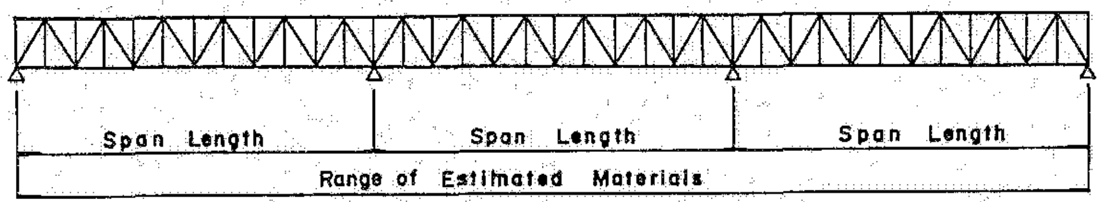
1) Types of structure.

Taking the necessary depth of foundation, importance of structures and favourable execution, well and multi-pile foundation were studied at first as the types of foundation. In Bangladesh, well foundation was frequently applied at Hardinge Bridge, King George IV Bridge in past and was executed in recent year as a bridge foundation at Dacca~Aricha Road. The merits of this method are large mass and good stability. But recently, piling method of large size steel pile has been developed and it is necessary that large size steel pile (78.7"~118" in diameter) is considered as group-pile foundation. These two methods were studied.

Table. 5-6 Rough Estimated Materials of Bridge Corresponding to Different Span.

	Item	Unit	Span			
			328'	492'	820'	1 148'
Case – a	Steel	t	2 392	4 806	9 628	20 308
	Concrete	yd^3	867	1 296	298	419
Case – b	Steel	t	3 198	6 380	15 169	27 880
	Concrete	yd^3	1 902	2 901	717	1 003

Marking Diagram for Span of 328' or 492'.



Marking Diagram for Span of 820' or 1 148'

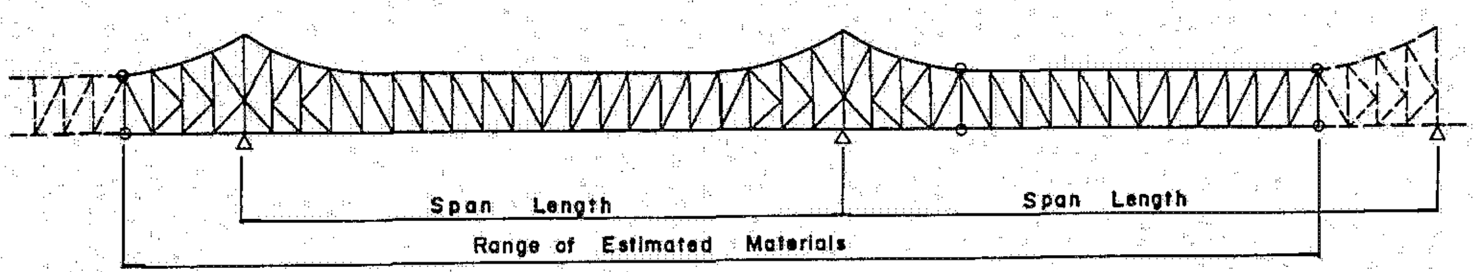


Table. 5-7-1 Material List of Superstructure (Case - a)

	Item	Unit	Span			
			328'- 1"	492'-1 1/2"	820'- 1 1/2"	1 148'- 3 1/2"
2.6 Mile Plan	Steel	t	33 516	46 504	89 838	128 376
	Concrete	yd^3	12 140	12 530	2 779	2 636
3.2 Mile Plan	Steel	t	41 354	56 121	109 128	169 035
	Concrete	yd^3	15 031	15 123	3 377	3 473
3.5 Mile Plan	Steel	t	44 694	60 929	109 128	169 035
	Concrete	yd^3	16 187	16 419	3 377	3 473

Table 5-7-2 Material List of Superstructure (Case - b)

	Item	Unit	Span			
			328'- 1"	492'- 1 1/2"	820'- 1 1/2"	1 148'-3 1/2"
2.6 Mile Plan	Steel	t	44 685	61 742	141 626	176 399
	Concrete	yd^3	26 625	28 044	6 672	6 328
3.2 Mile Plan	Steel	t	55 502	74 507	172 028	232 240
	Concrete	yd^3	32 964	33 846	8 107	8 337
3.5 Mile Plan	Steel	t	59 832	80 889	172 028	232 240
	Concrete	yd^3	35 499	36 747	8 107	8 337

In the case of multi-pile-foundation, top of pile and base slab of pier must be connected rigidly and such connecting work must be done in dry season.

The base slab of this type of pier requires high rigidity because of the theoritical reason. As the length of free portion of the pile is long, such a structure forms a flexible and top heavy one. This means a undesirable structure in view of the structural mechanics and is easily deflected by horizontal force such as inertia force due to earthquake or current pressure.

Therefore, we adopted the well foundation as the Jamuna River Bridge foundation from the engineering and economical points of view. As for the local scouring around the piers, well foundation seems to be larger than multi-pile-foundation. In future, it will be necessary to prevent the pier from scouring in order to secure the required grip of well in accordance with necessity.

2) Outline of structure.

As for the foundation of the Jamuna River Bridge, it was concluded that the well foundation is the most suitable one. But some difficulties will be expected for the method of execution, because the well must be sunk during the dry season.

In order to carry out this purpose, we think that the reverse circulation method is one of the most desirable one. In this case, some devices which reduce the frictional resistance between the curbshoe, body of well and the surrounding soil must be considered. The sinking velocity of well depends on the weight of well itself, therefore it is desirable that the thickness of wall of well should be as thick as practicable in order to accelerate the sinking velocity of well.

The height of top of well is 1m (3.3ft) above the MLLWL. The definite length of grip of well must be needed to maintain a stability against lateral force. Therefore, some foot protection works around pier and their constant inspection and maintenance will be requested in future to secure the constant length of grip of well (See Figs. 5-5-1 and 5-5-2).

3) Materials.

Major materials of the substructure of the Jamuna River Bridge for each of the four proposed sites by two types of guide bank were shown in Table 5-8.

(4) Approaches.

1) Enbankment.

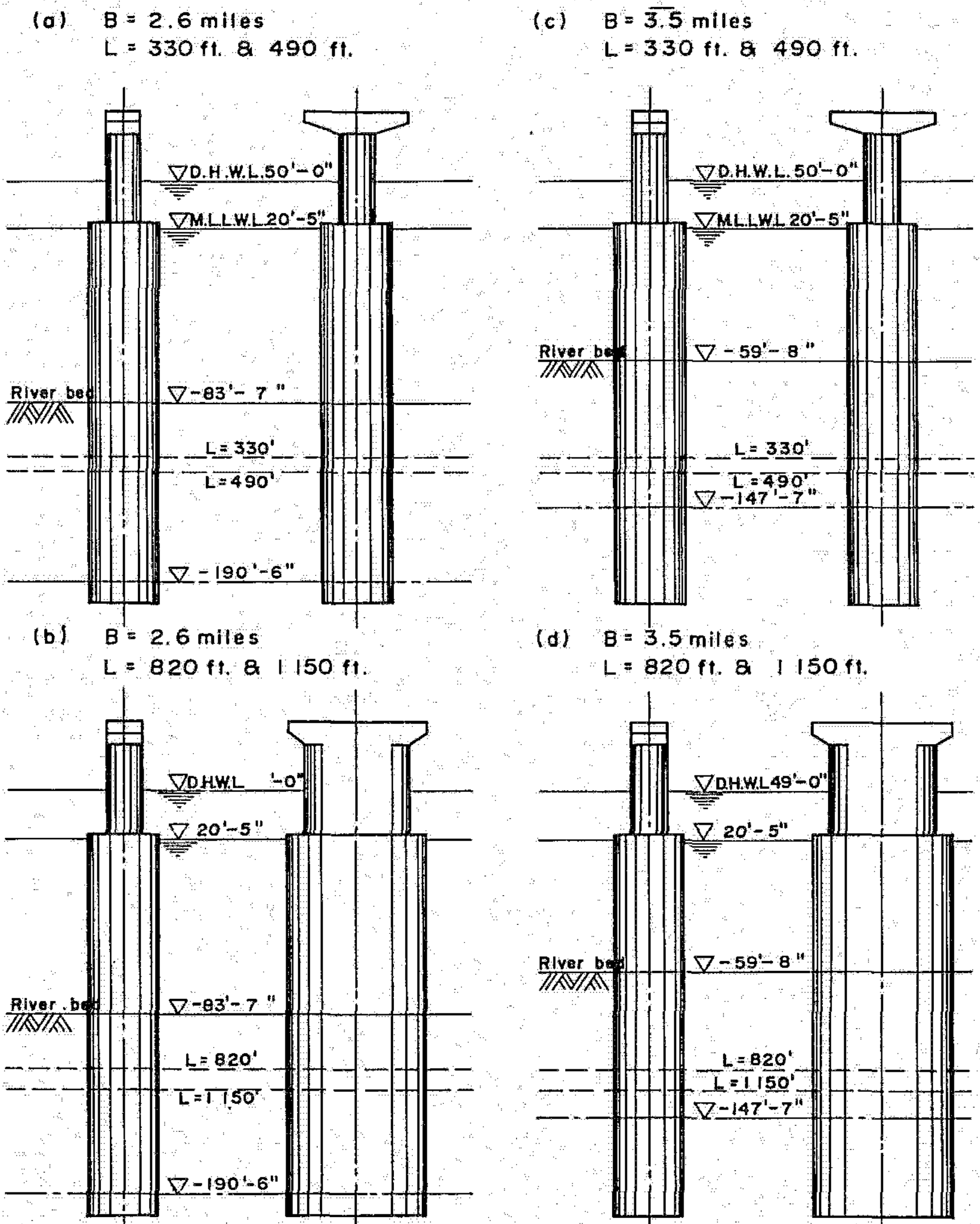
The length of embankment in approaches is affected by the longitudinal slope of railway. Because of the design height of formation level of railway for the Jamuna River Bridge is about 90 ft above the DHWL, embankment of about 2.2 miles of length will be required, provided that the longitudinal slope of railway is 1/200. In the kadir part of embankment, closing dyke was constructed to dam up a water as shown in Chapter IV. In the land part of embankment, it was constructed from existing ground level to the DHWL by the same method as closing dyke.

The formation level of closing dyke is the same height of the DHWL and the embankment of approaches is constructed on the closing dyke. The soil which has good mechanical properties will be requested for this embankment.

The requested mechanical properties of soil are as follows.

a. Unit weight 1.9 t/m^3(119 lbs/cft)

Fig.5-5-1 Necessary Length of Grip Required for Stability of Well (Case-a) at Sirajganj Site.



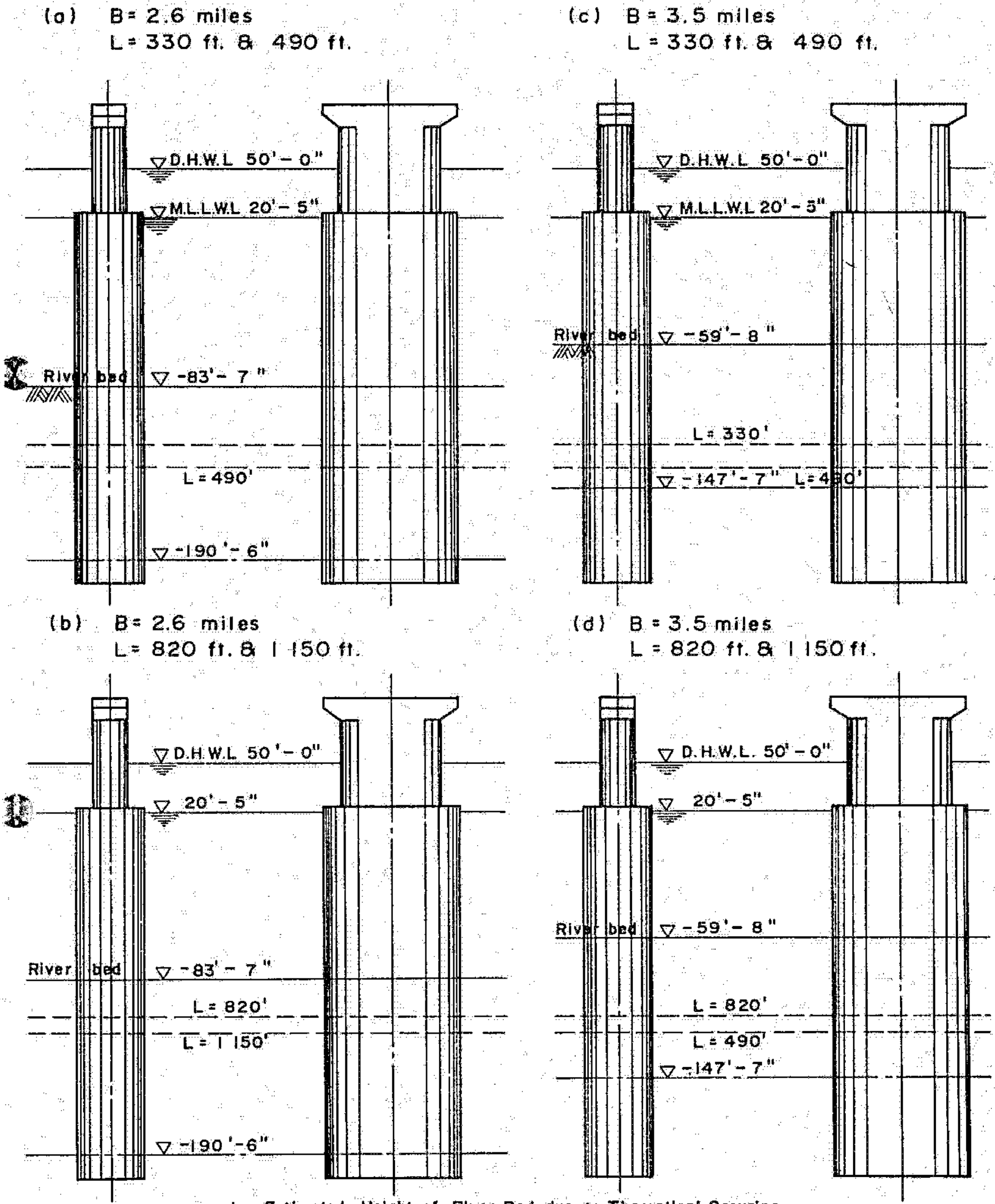
——·——·—— : Estimated Height of River Bed due to Theoretical Scouring

— — — — — : Height of River Bed required for Stability of Well.

B : Distance between Guide Banks.

L : Span Length of Bridge.

Fig.5-5-2 Necessary Length of Grip Required for Stability of Well (Case-b) at Sirajganj Site.



——— : Estimated Height of River Bed due to Theoretical Scouring.

– – – – : Height of River Bed required for Stability of Well.

B : Distance between Guide Banks.

L : Span Length of Bridge.

Table.5-8-1 List of Rough Estimated Basic Materials of Construction for Jumuna River Bridge at Each Site.

Sites Proposed for Bridge Construction		ITEMS	UNIT	QUANTITIES 2.6 mile	3.2 mile	3.5 mile
	Bahadurabad	Coment	ton	71.000		94.000
		Fine Aggregate	100cf	34.000		44.000
		Coarse Aggregate	"	67.000		88.000
		Steel Bar	ton	17.000		22.000
		Structural Steel	"	47.000		62.000
	Gabargaon	Coment	"	72.000	88.000	
		Fine Aggregate	100cf	34.000	41.000	
		Coarse Aggregate	"	68.000	83.000	
		Steel Bar	ton	17.000	21.000	
		Structural Steel	"	47.000	57.000	
	Sirajganj	Coment	"	69.000		92.000
		Fine Aggregate	100cf	32.000		43.000
		Coarse Aggregate	"	65.000		86.000
		Steel Bar	ton	16.000		21.000
		Structural Steel	"	47.000		62.000
	Nagarbari	Coment	"	77.000	94.000	
		Fine Aggregate	100cf	36.000	44.000	
		Coarse Aggregate	"	73.000	88.000	
		Steel Bar	ton	18.000	22.000	
		Structural Steel	"	47.000	57.000	

Type of Superstructure ; 3-Span Continuous Steel Truss.
3 @ 490 ft. (2-Lanes, Single Track)
Type of Substructure ; Well Foundation (ø 12 m)

Table.5-8-2 List of Rough Estimated Basic Materials of Construction for Jamuna River Bridge at Each Site.

Sites Proposed for Bridge Construction		ITEMS	UNIT	QUANTITIES		
				4.2 km	5.2 km	5.6 km
	Bahadurabad	Cement	ton	121.000		160.000
		Fine Aggregate	100cf	57.000		75.000
		Coarse Aggregate	"	114.000		151.000
		Steel Bar	ton	28.000		37.000
		Structural Steel	"	62.000		82.000
	Gabargaon	Cement	"	124.000	150.000	
		Fine Aggregate	100cf	58.000	71.000	
		Coarse Aggregate	"	117.000	142.000	
		Steel Bar	ton	28.000	37.000	
		Structural Steel	"	62.000	76.000	
	Sirajganj	Cement	"	118.000		157.000
		Fine Aggregate	100cf	56.000		74.000
		Coarse Aggregate	"	112.000		147.000
		Steel Bar	ton	28.000		37.000
		Structural Steel	"	62.000		82.000
	Nagarbari	Cement	"	132.000	160.000	
		Fine Aggregate	100cf	62.000	75.000	
		Coarse Aggregate	"	124.000	150.000	
		Steel Bar	ton	31.000	37.000	
		Structural Steel	"	62.000	76.000	

Type of Superstructure ; 3-Span Continuous Steel Truss.
3 @ 490 ft. (4-Lanes, Double Track)
Type of Substructure ; Well Foundation (ø 12x24).

b. Internal Friction Angle $\phi = 30^o$

c. Cohesion of soil C = 0

Taking the surcharge on embankment due to railway and highway into consideration, stability calculation by circular arc method was performed under the condition of slop gradient 1:2. From this calculation, stablity of slope was confirmed but 1:2.5 of designed slope gradient was adopted from safety side at present state in view of safety.

Instead of high embankment, viaduct is considered partly but because of embankment is cheaper than viaduct, the former was adopted in approaches.

2) Viaduct.

In the case of b which is double track in railway part and four lanes carriageway in highway part, the Jamuna River Bridge have a double deck type and railway run through the lower part and vehicles run the upper part of the bridge.

In highway running the upper part, viaduct is needed for leveling down to a level of approach road.

Steel continuous box girders were adopted as viaduct type and considerating with minimizing the total cost and with shifting alignment from the center line of railway, 3 @ 197 ft was assumed as the standard span. But in the portion where the highway part overlaps with railway part, portal type of piers was applied for the highway part.

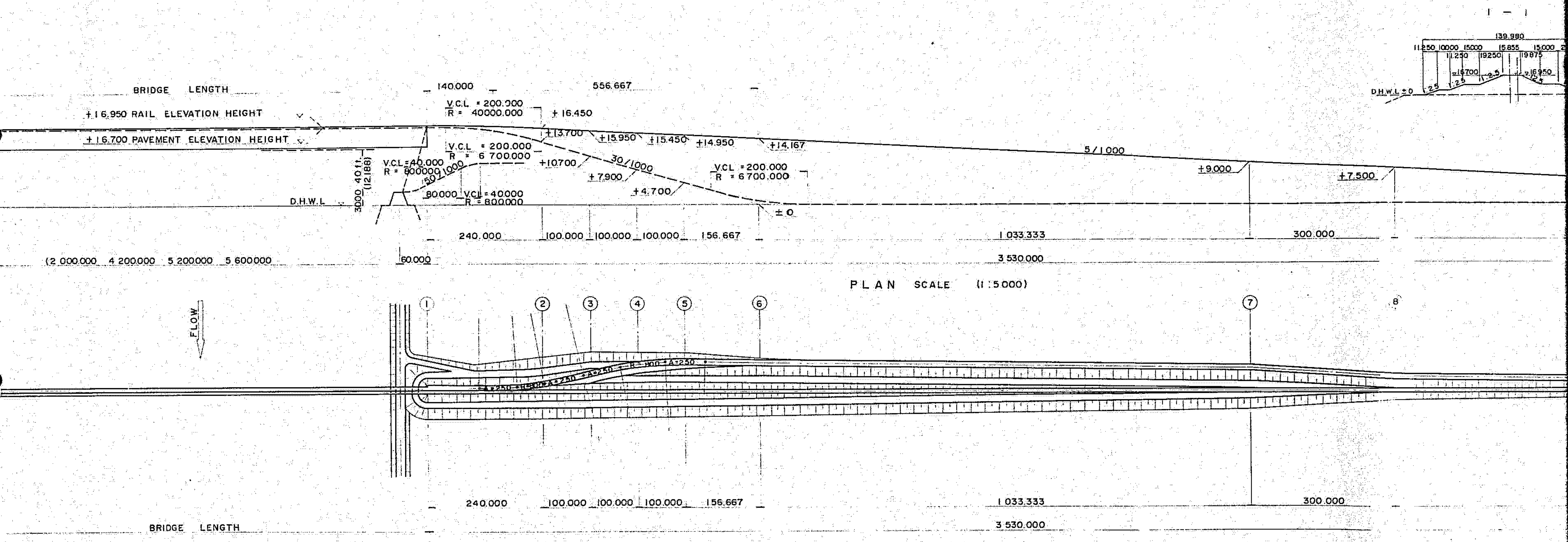
3) Quantity of materials.

Approach parts will be constructed in the same style at both side over the Jamuna River.

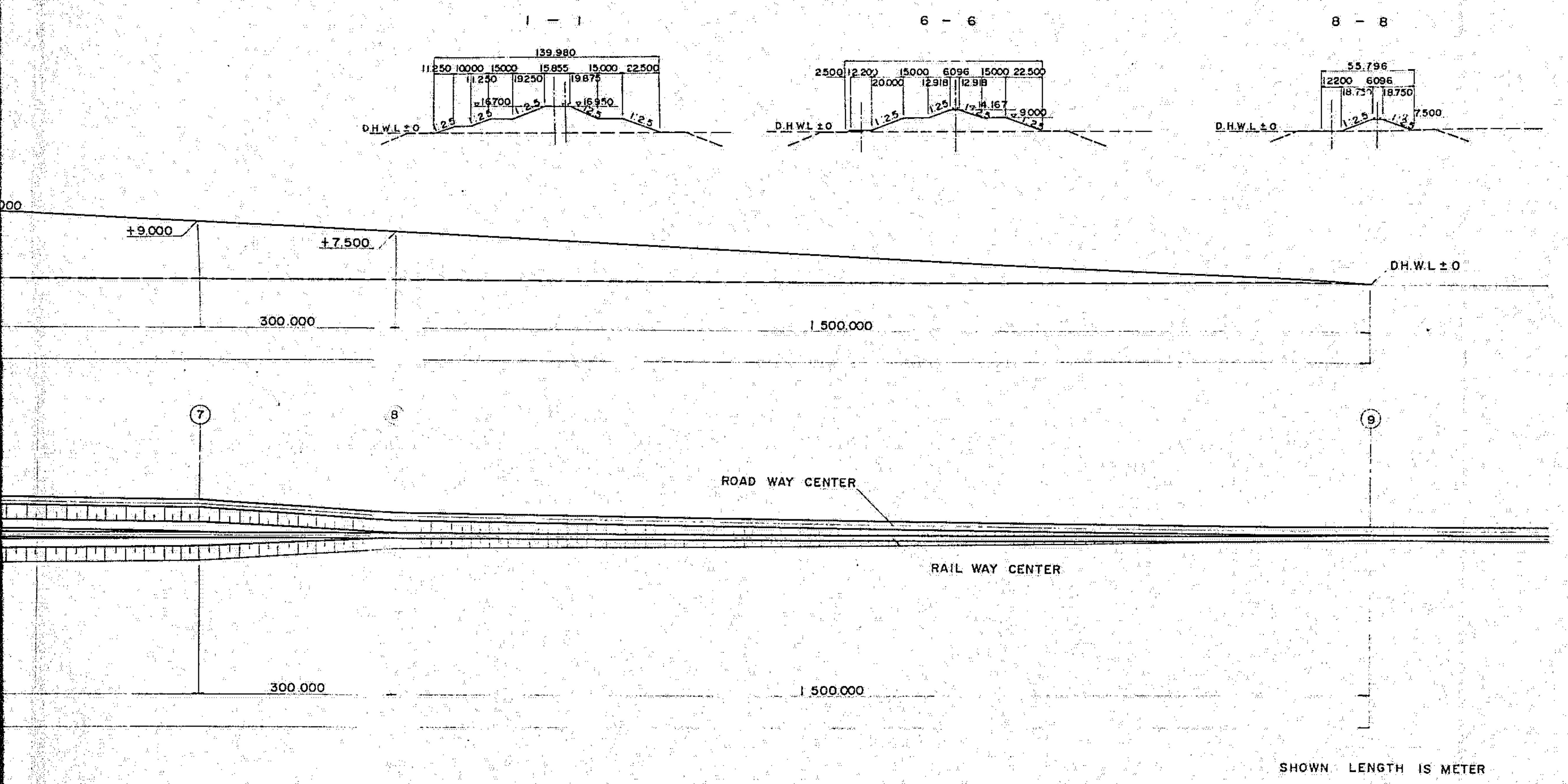
General volume of earth work at one side of approach and its sodding area were shown in Table 5-9.

In the case of b, approximate weight of steel of viaduct was shown in Table 5-9 per one side.

Fig.5-6-1 JAMUNA RIVER BRIDGE APPROACH (SINGLE TRACK RAILWAY & TWO LANE ROAD)

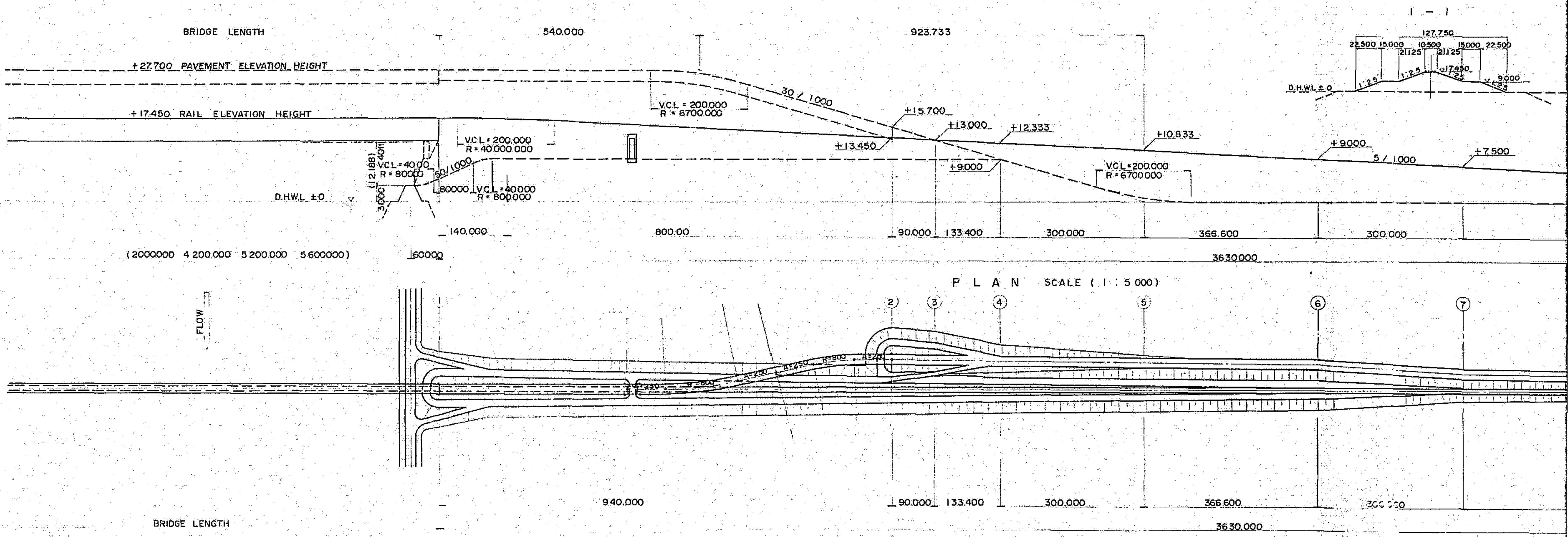


AY & TWO LANE ROAD)

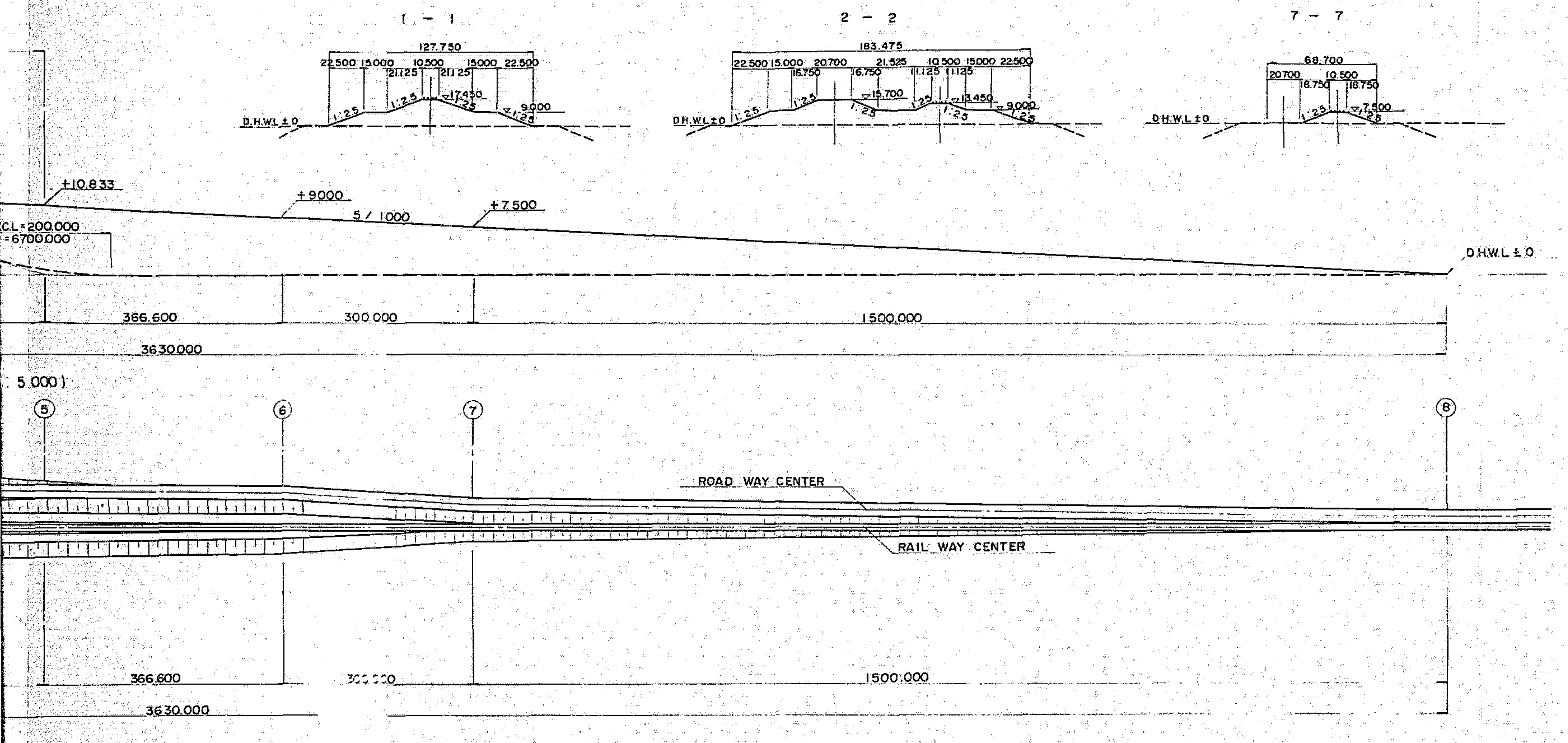


JAPAN INTERNATIONAL COOPERATION AGENCY
PEOPLE'S REPUBLIC OF BANGLADESH
JAMUNA RIVER BRIDGE PROJECT
APPROACH ROAD OF LEFT BANK (SINGLE TRACK & TWO LANES)
Drawn Date
Approved Date
NIKKEN CONSULTANTS INC. Fig. 5-6-1

Fig. 5-6-2 JAMUNA RIVER BRIDGE APPROACH (DOUBLE TRACK RAILWAY & FOUR LANE R



CH (DOUBLE TRACK RAILWAY & FOUR LANE ROAD)



SHOWN LENGTH IS METER

JAPAN INTERNATIONAL COOPERATION AGENCY

PEOPLE'S REPUBLIC OF BANGLADESH

JAMUNA RIVER BRIDGE PROJECT

APPROACH ROAD OF LEFT BANK
(DOUBLE TRACK & FOUR LANES)

Drawn	Date
Approved	Date
NIKKEN CONSULTANTS INC.	Fig. 5-6-2

Table. 5-9 Material List of Approach Road per One Side of Jamuna River Bridge

Items			Unit	Case -a	Case - b
Earth Work			10^3cft.	61 400	90 400
Sodding			10^3sft.	1 500	2 200
Length of Highway part of Embankment.			mile	2.19	1.67
Part of Highway Viaduct	Structural Steel	Superstructure	t	——	3 700
		Rahmen Pier	"	——	1 250
	Foundation	Concrete	10^3cft.	——	452
		Steel Pipe Pile	t	——	2 800

Note ; Above figures of earth work show the figures of earth work over the D.H.W.L. excluding the earth work under the D.H.W.L.

(5) The most suitable type of structure of the Jamuna River Bridge.

Generally speaking, the cost of superstructure increases extremely in accordance with the increase of its clear span length. According to the increase of clear span of bridge, it is natural that the load acting each pier should increase corresponding to the increment of clear span, therefore, the scale of substructure will be enlarged. But naturally, number of piers decrease in accordance with the increment of clear span of bridge.

It is clarified by our study that the share of cost of substructure in the total cost of construction is not so high. Owing to the results of our calculation, the relation between clear span length and cost of construction is shown by Fig. 5-7-1~Fig. 5-7-4. As shown in figures, the curve tends to convex downward. This means that the clear span corresponding to the bottom point of the curve is the most economical one.

According to the above-mentioned analysis, in this project, the most economical clear span will be found between 150m and 200m. Such investigations will be carried out at the second stage of the study. But at the first stage of the study, three span continuous truss of 150m(492 ft) of clear span was adopted as the basis of the selection of site.

Fig. 5-8-1~Fig. 5-8-4 show the general view of four types of bridge in the case of 2.6 miles of width of guide banks.

4. Bridge in Access Part.

As for the type of superstructure of bridge included in the domain of railway and highway access, we adopted the prestressed concrete bridge throughly. Composition of span was decided by the next two facters. These factors are navigation clearance of river and total cost of construction of bridge. In the latter factor, composition of span is affected by the well or pile foundation. The well foundation will be adopted for the place where local scouring seems to be expected and the pile foundation will be adopted for the other sites.

Types and composition of span of bridges included in railway access are shown in Table 5-10-1 and those in highway access are shown in Table 5-10-2 respectively.

In the access part, railway bridge and highway bridge were treated independently.

Fig. 5-7-1 The Relation between Construction Costs and Span of Jumuna River Bridge. Case-a with Well Foundations.

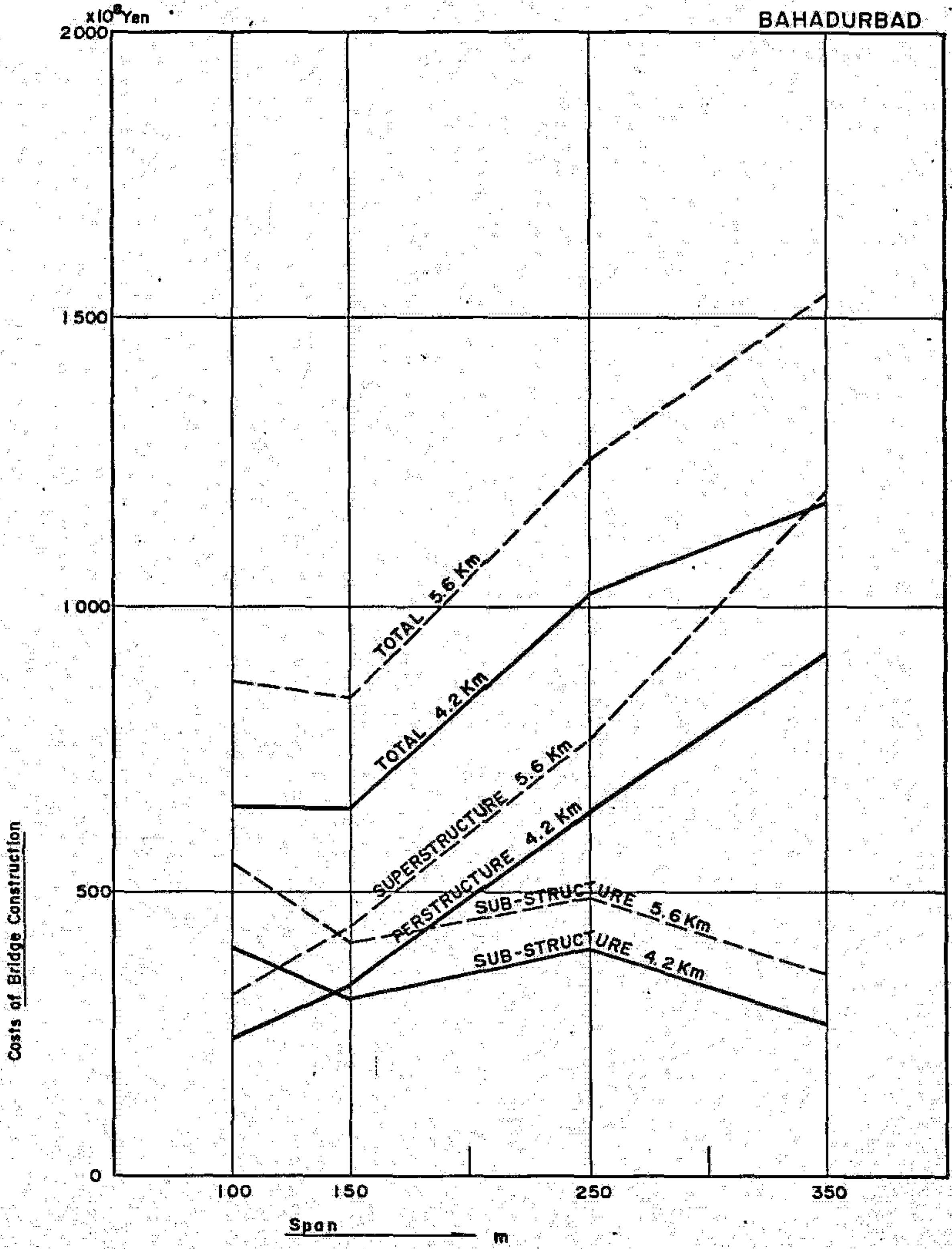


Fig. 5-7-2 The Relation between Construction Costs and Span of Jumuna River Bridge. Case-a with Well Foundations.

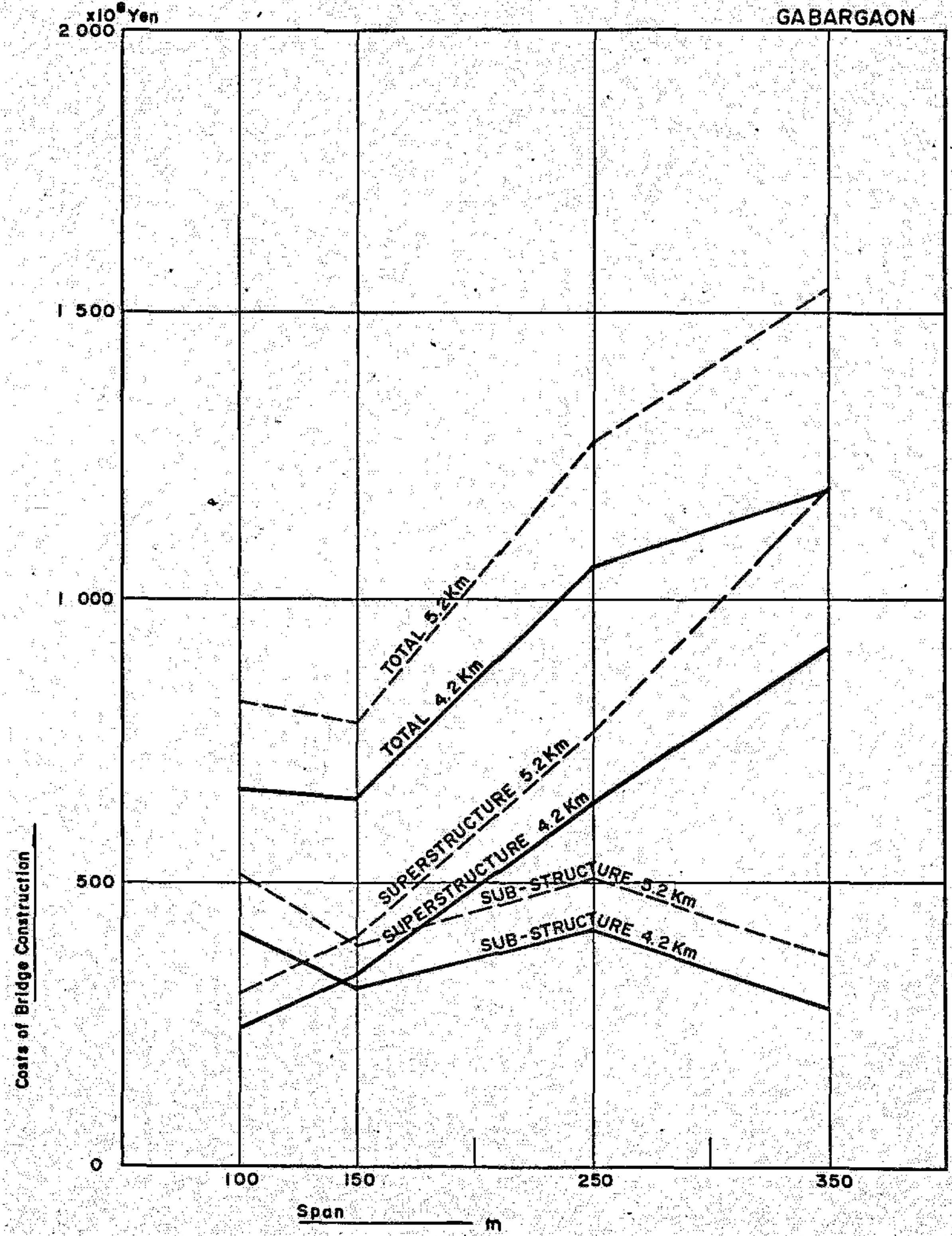


Fig. 5-7-3 The Relation between Construction Costs and Span of Jumuna River Bridge. Case-a with Well Foundations.

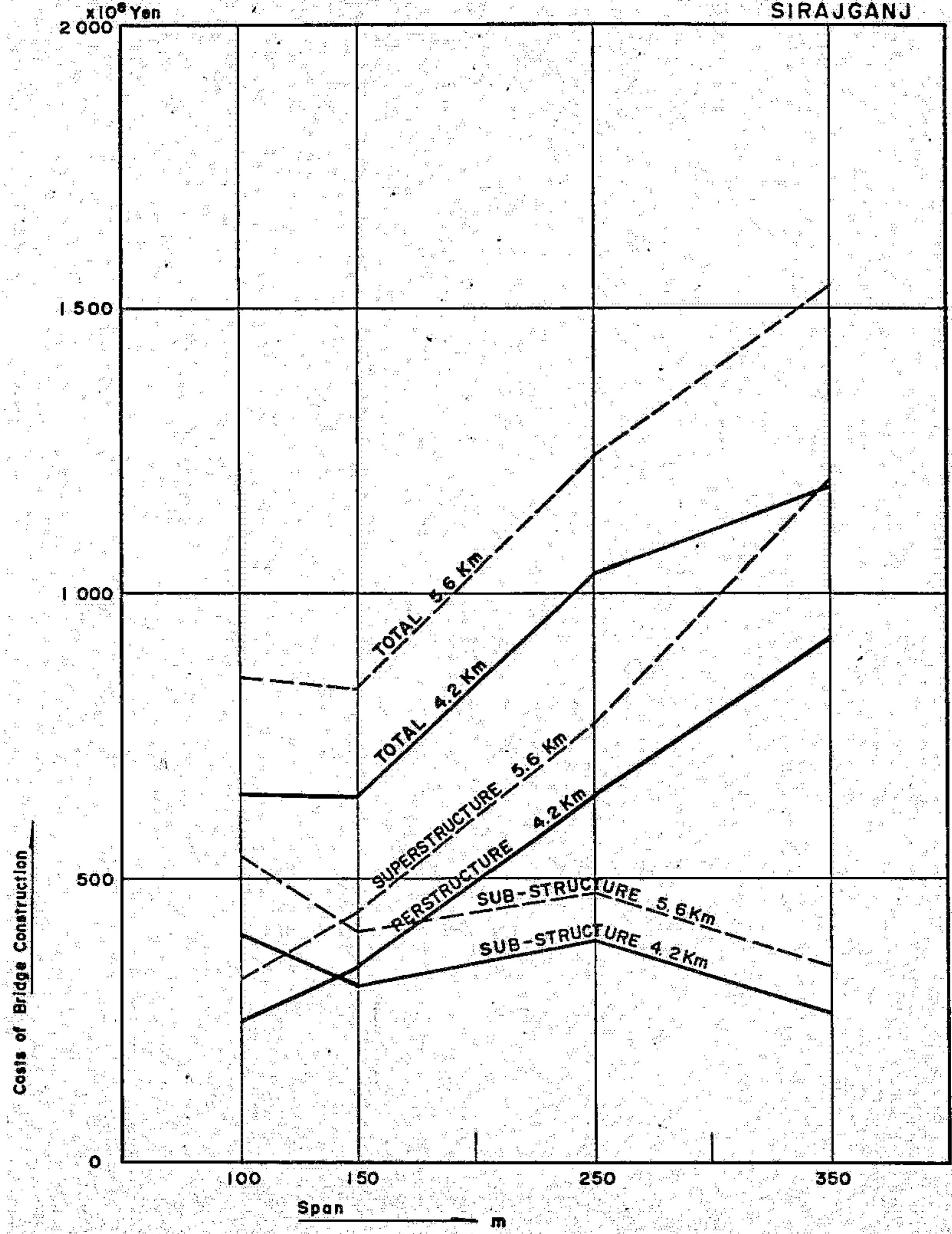


Fig. 5-7-4 The Relation between Construction Costs and Span of Jumuna River Bridge. Case-a with Well Foundations.

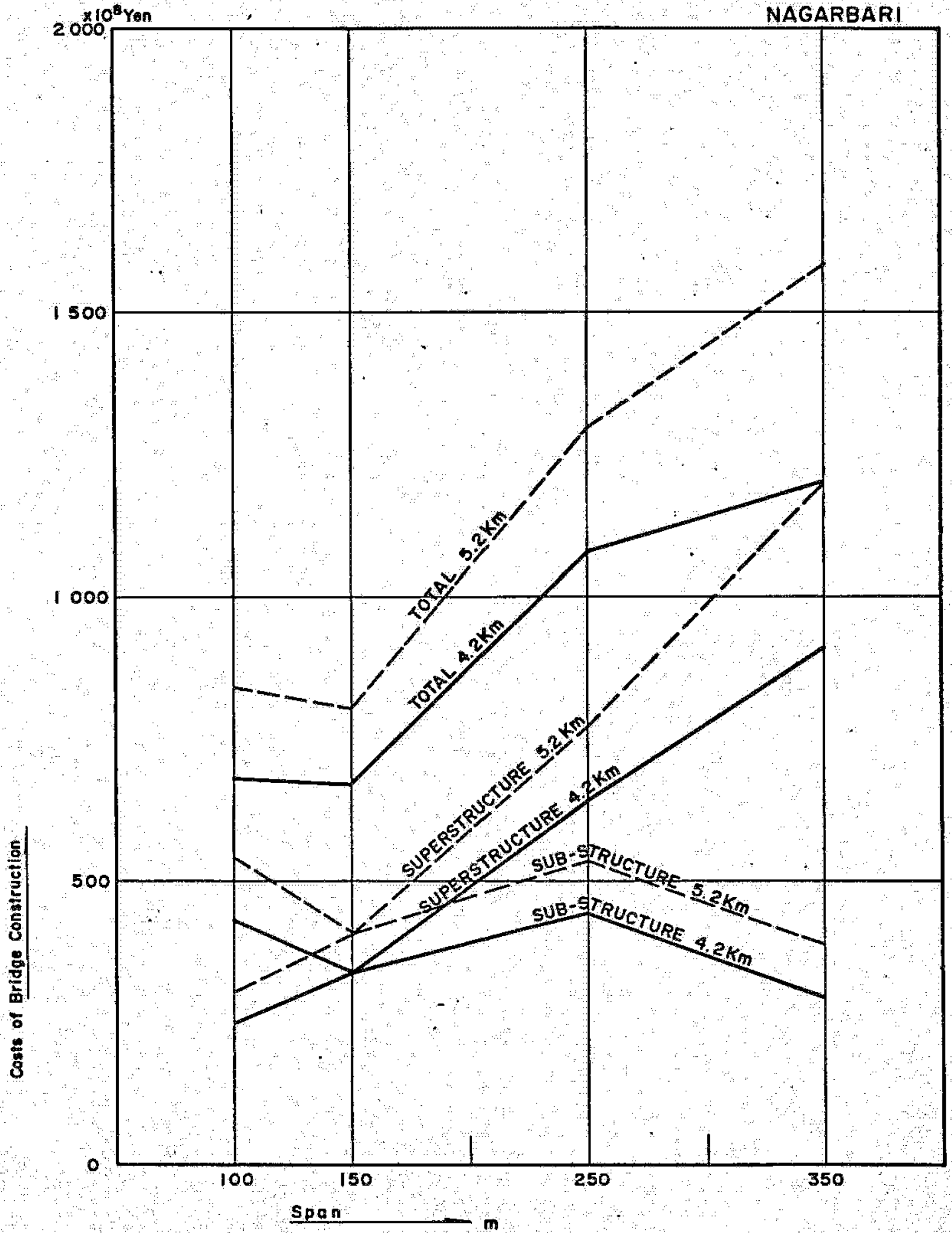
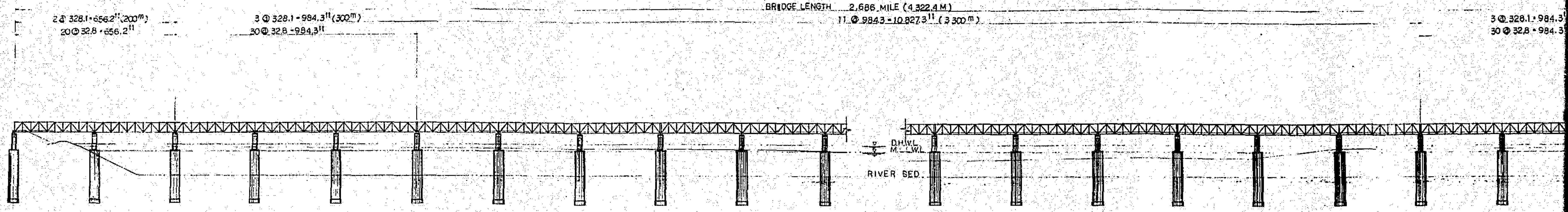


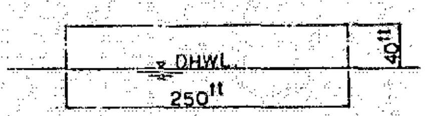
Fig. 5-8-1

GENERAL VIEW OF JAMUNA RIVER BRIDGE
(RAIL-CUM-HEIGHWAY)
CONTINUOUS TRUSS
DISTANCE BETWEEN GUIDE BANKS 2.610 MILE (4.2 KM)

PROFILE SCALE 1:4000

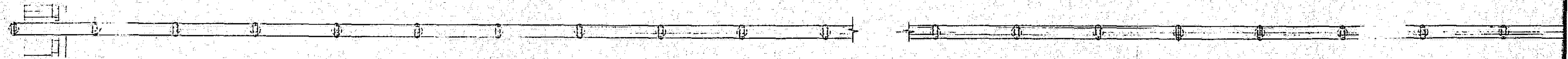


NAVIGATION CLEARANCE SCALE 1:2000

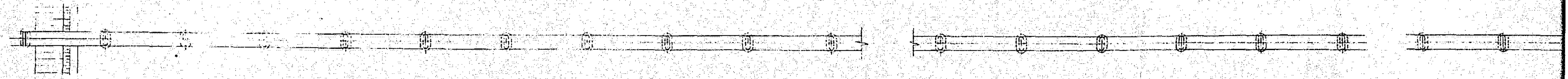


PLAN SCALE 1:4000

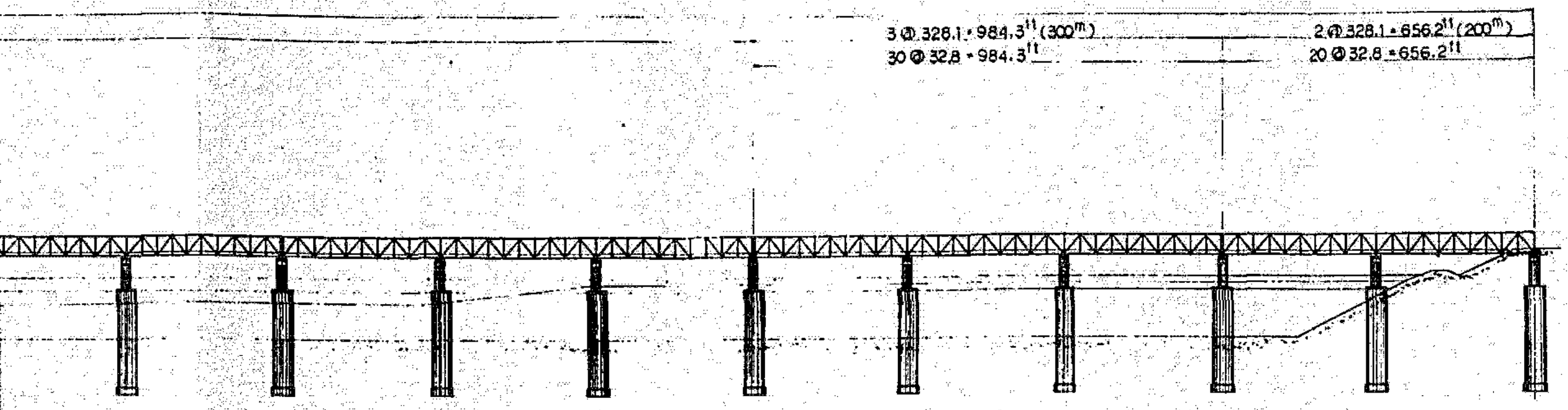
CASE-A



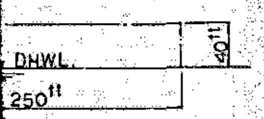
CASE-B

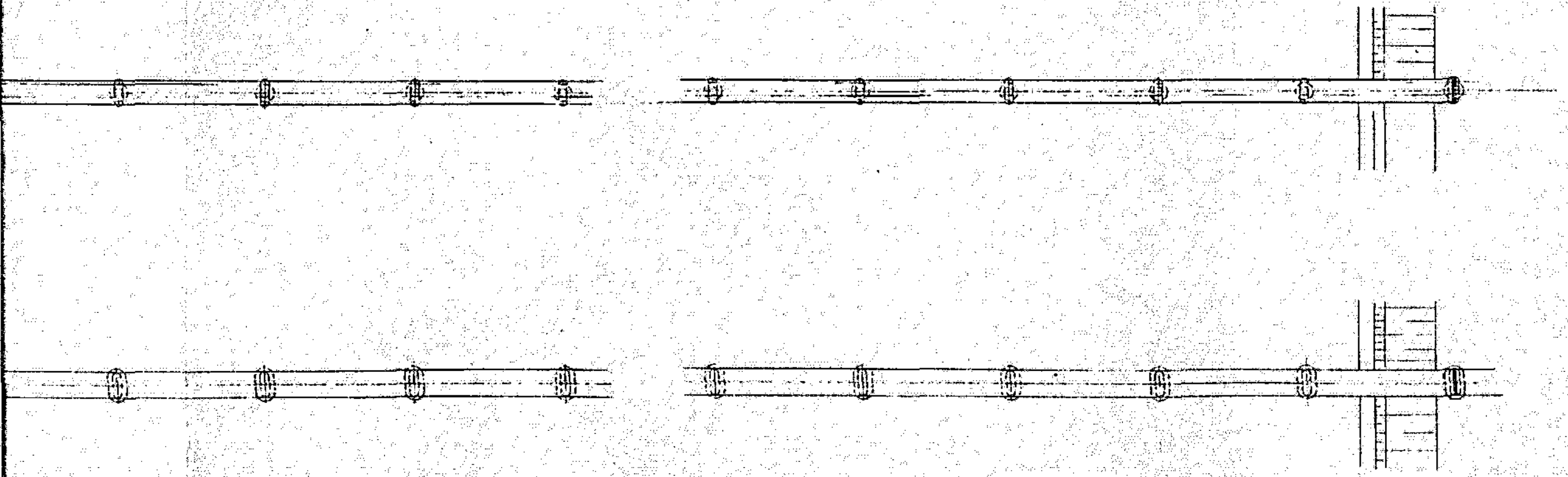


OF JAMUNA RIVER BRIDGE
CUM-HEIGHWAY)
UOUS TRUSS
GUIDE BANKS' 2.610 MILE (4.2 KM)

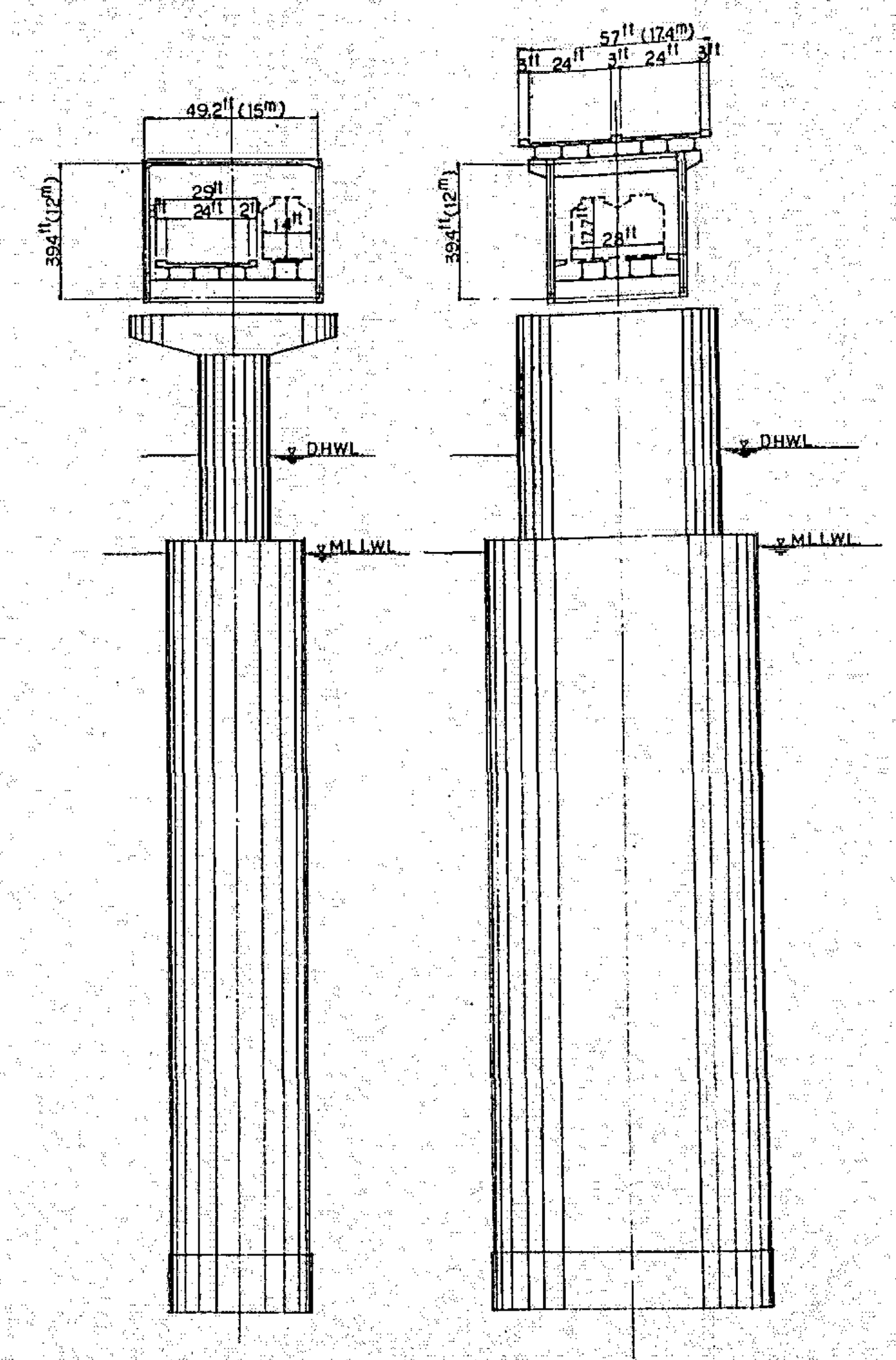


ON CLEARANCE SCALE 1:2000





TYPICAL CROSS SECTION SCALE 1:600



JAPAN INTERNATIONAL COOPERATION AGENCY	
PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE PROJECT GENERAL VIEW DISTANCE BETWEEN PIERS 328.1ft	
Drawn	Date
Approved	Date
NIKKEN CONSULTANTS INC.	Fig. 5-8-1

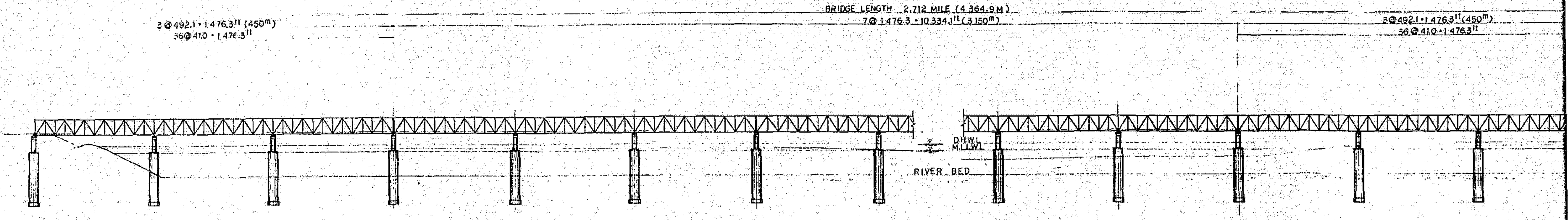
Fig. 5-8-2

GENERAL VIEW OF JAMUNA RIVER BRIDGE
(RAIL – CUM – HEIGHWAY)

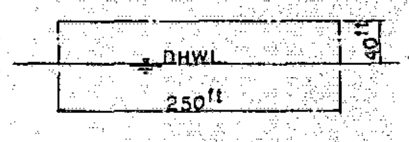
CONTINUOUS TRUSS

DISTANCE BETWEEN GUIDE BANKS 2.610 MILE (4.2 KM)

PROFILE SCALE 1:4000

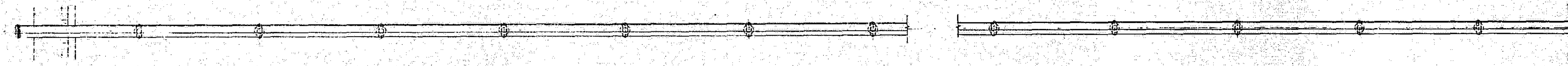


NAVIGATION CLEARANCE SCALE 1:2000



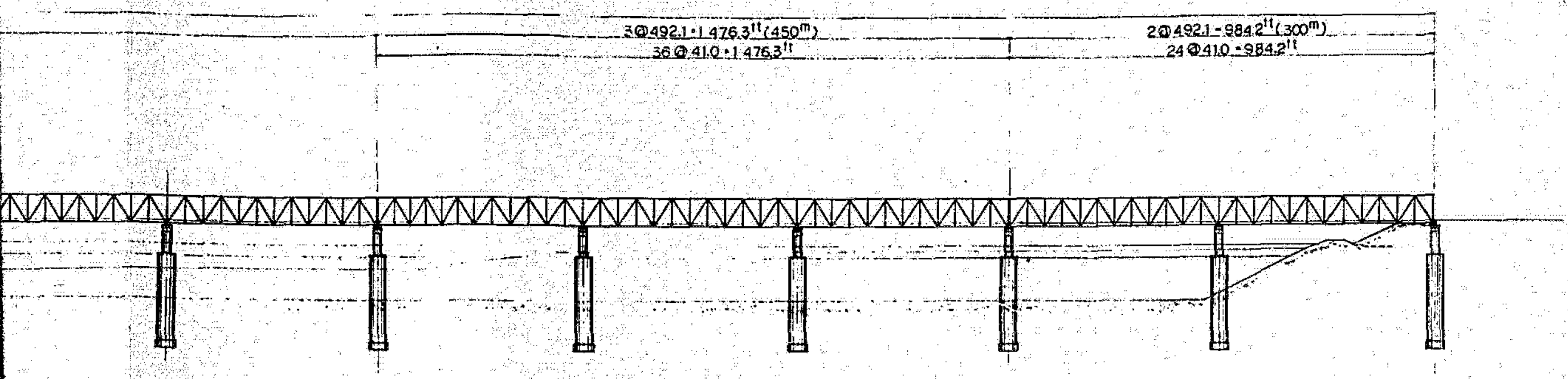
PLAN SCALE 1:4000

CASE – a

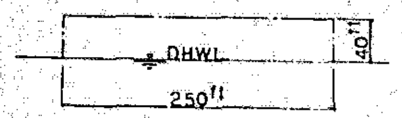


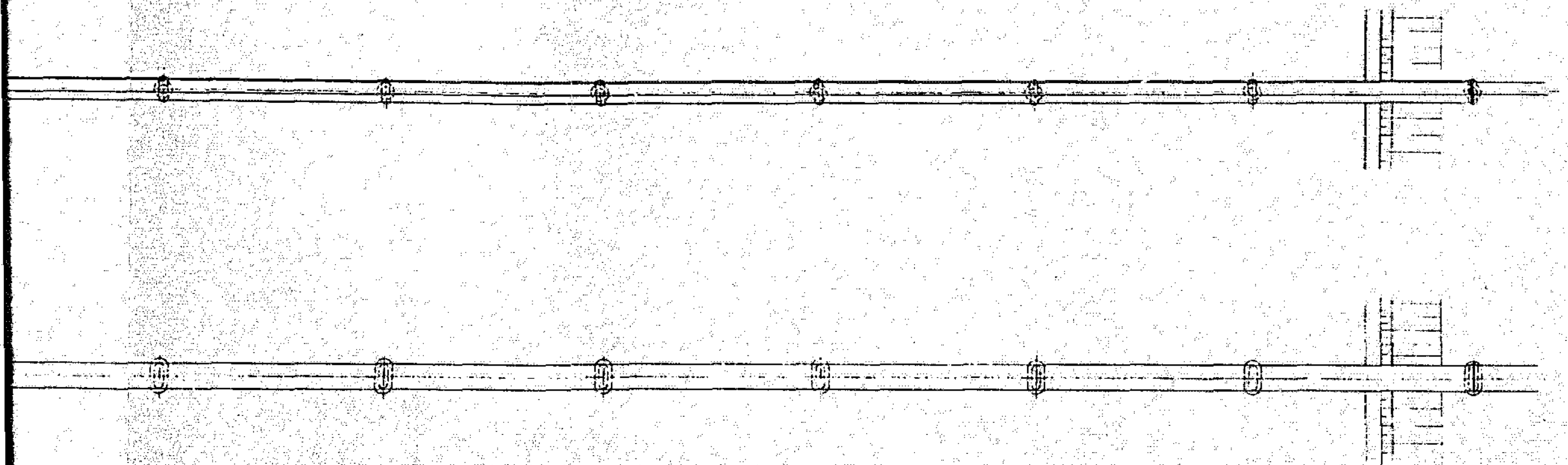
CASE – b

EW OF JAMUNA RIVER BRIDGE
CUM - HEIGHWAY)
NTINUOUS TRUSS
EEN GUIDE BANKS 2.610 MILE (4.2KM)



NAVIGATION CLEARANCE SCALE 1:2000

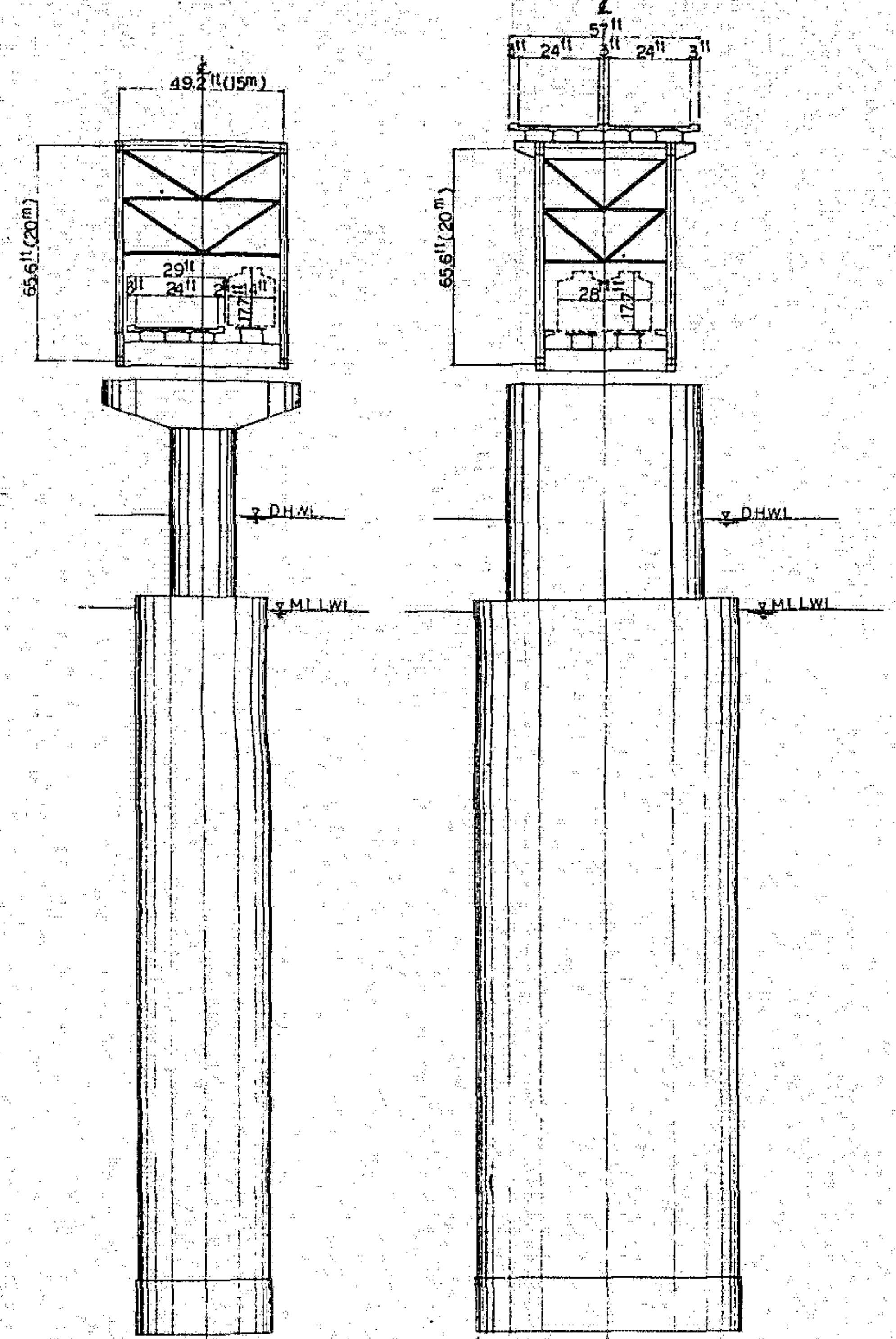




TYPICAL CROSS SECTION SCALE 1:600

CASE - a

CASE - b



JAPAN INTERNATIONAL COOPERATION AGENCY
PEOPLE'S REPUBLIC OF BANGLADESH
JAMUNA RIVER BRIDGE PROJECT GENERAL VIEW DISTANCE BETWEEN PIERS 492.1ft
Drawn Date
Approved Date
NIKKEN CONSULTANTS INC. Fig.5-8-2

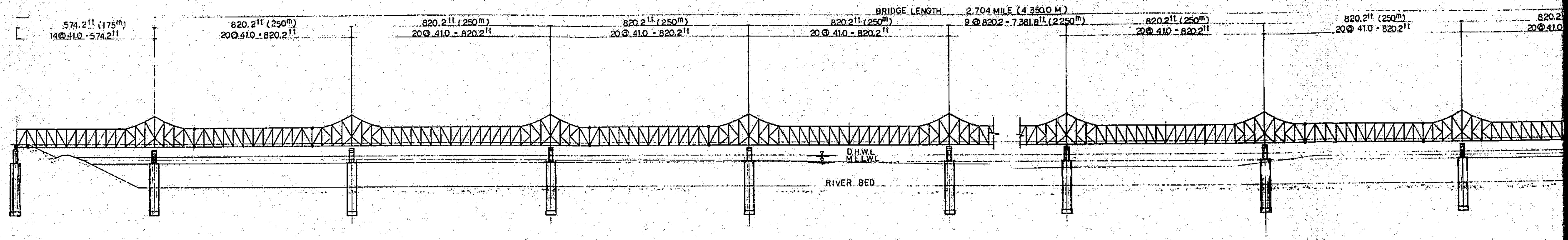
Fig. 5-8-3 GENERAL VIEW OF JAMUNA RIVER BRIDGE

(RAIL-CUM-HEIGHWAY)

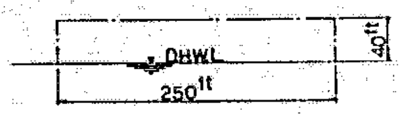
CANTILEVER TRUSS

DISTANCE BETWEEN GUIDE BANKS 2.610 MILE (4.2 KM.)

PROFILE SCALE 1:4000

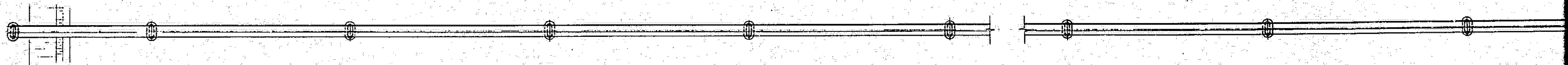


NAVIGATION CLEARANCE SCALE 1:2000

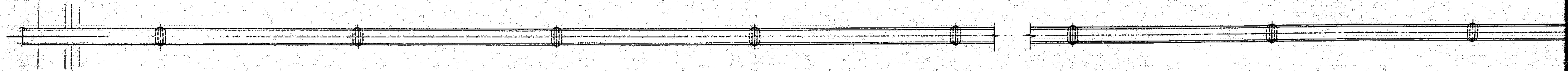


PLAN SCALE 1:4000

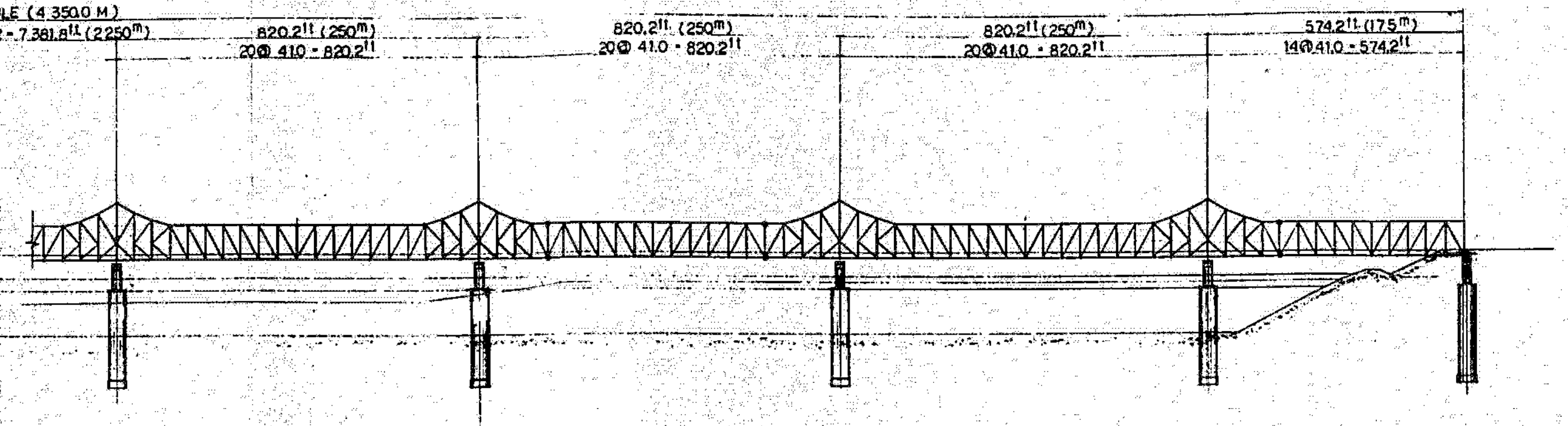
CASE - a



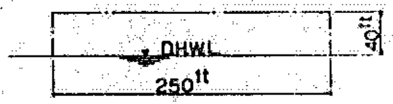
CASE - b

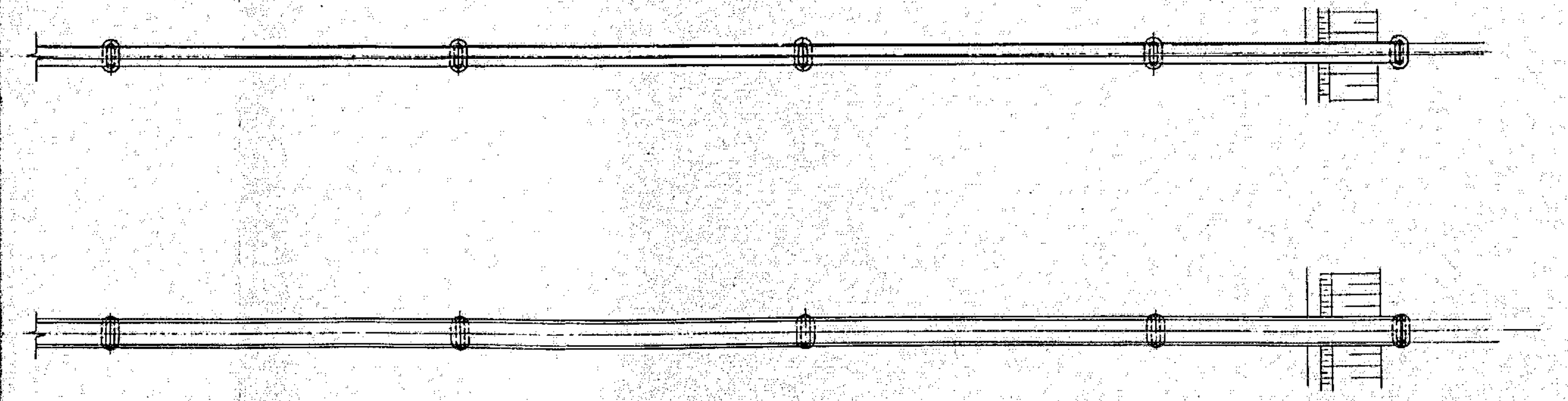


EW OF JAMUNA RIVER BRIDGE
L-CUM-HEIGHWAY)
NTILEVER TRUSS
N GUIDE BANKS' 2.610 MILE (4.2 KM.)

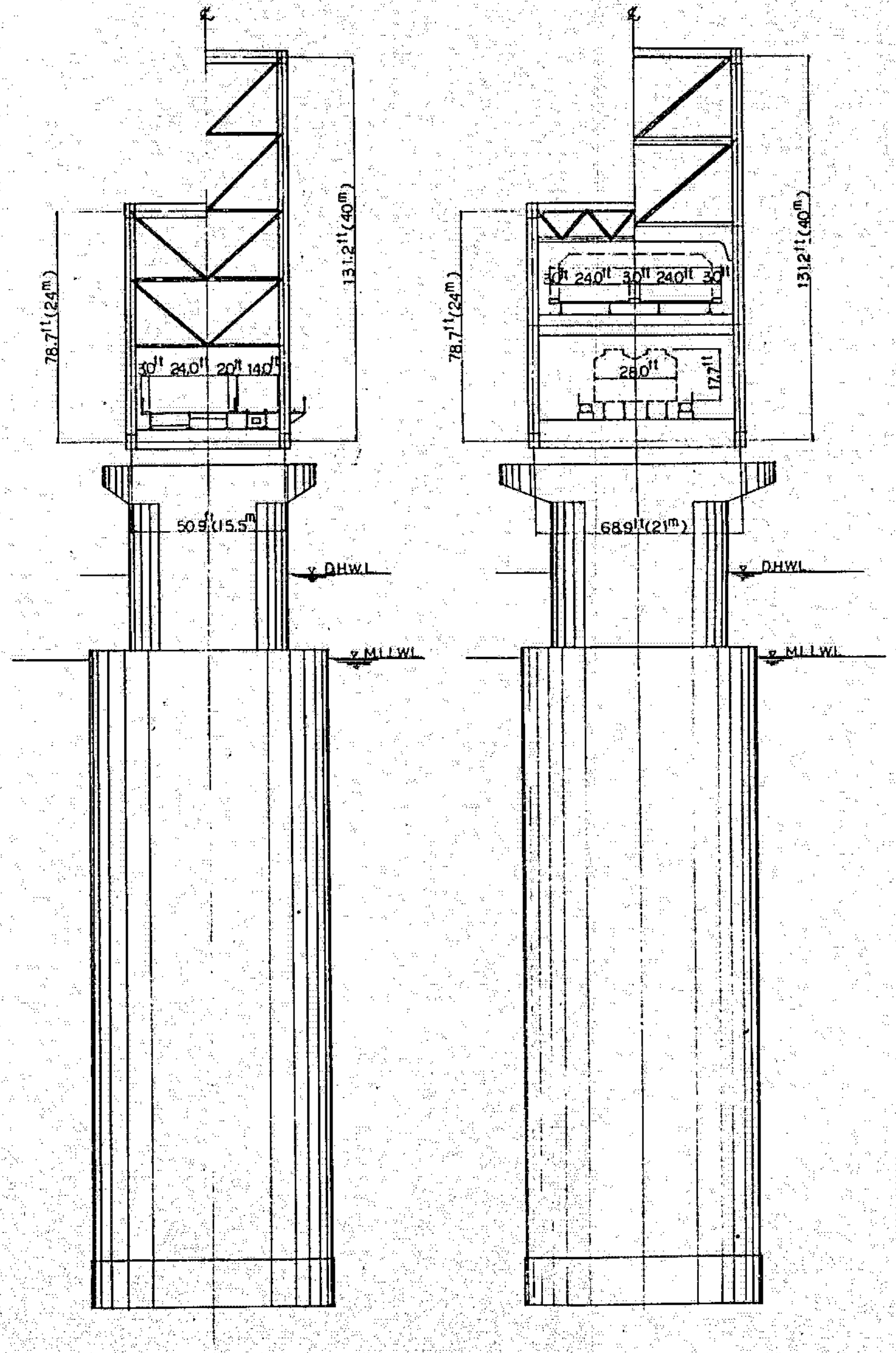


NAVIGATION CLEARANCE SCALE 1:2000





TYPICAL CROSS SECTION SCALE 1:600



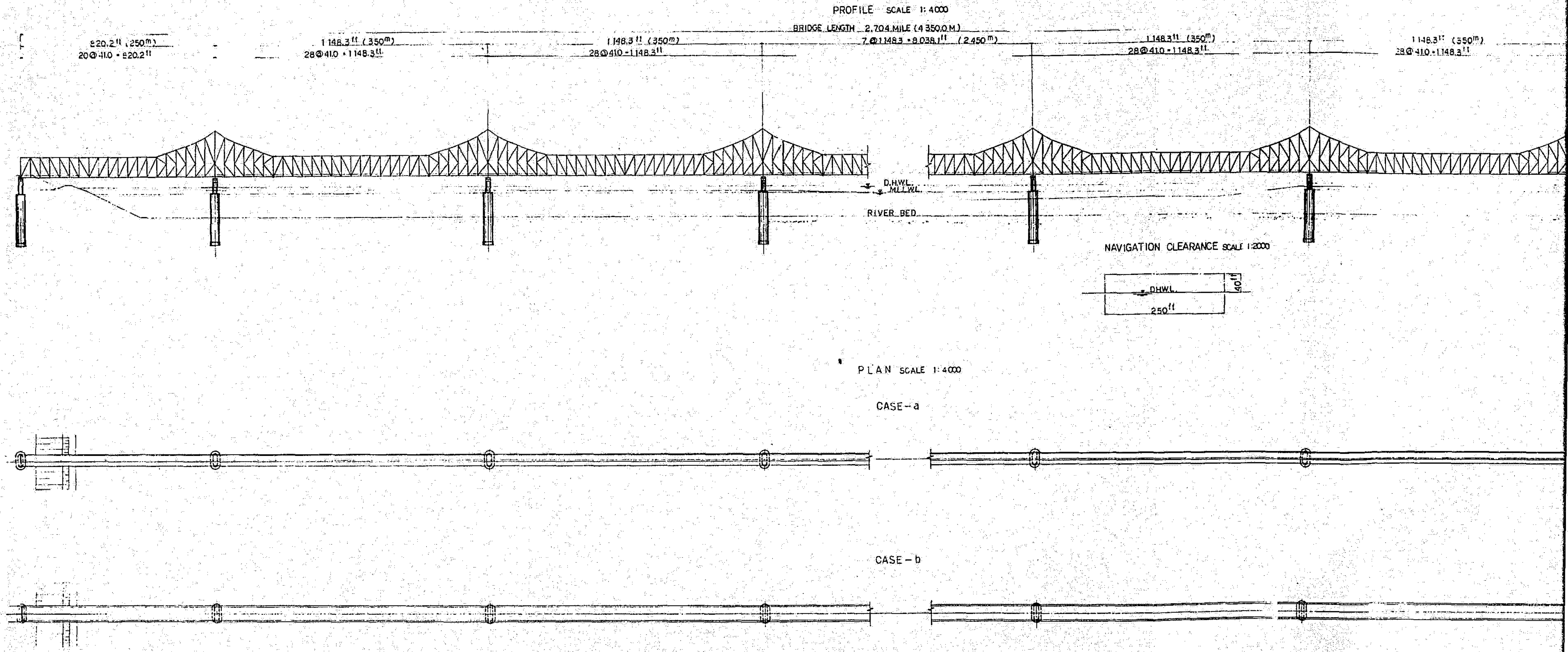
JAPAN INTERNATIONAL COOPERATION AGENCY	
PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE PROJECT GENERAL VIEW DISTANCE BETWEEN PIERS 820.2ft	
Drawn	Date
Approved	Date
NIKKEN CONSULTANTS INC.	Fig. 5-8-3

Fig. 5-8-4 GENERAL VIEW OF JAMUNA RIVER BRIDGE

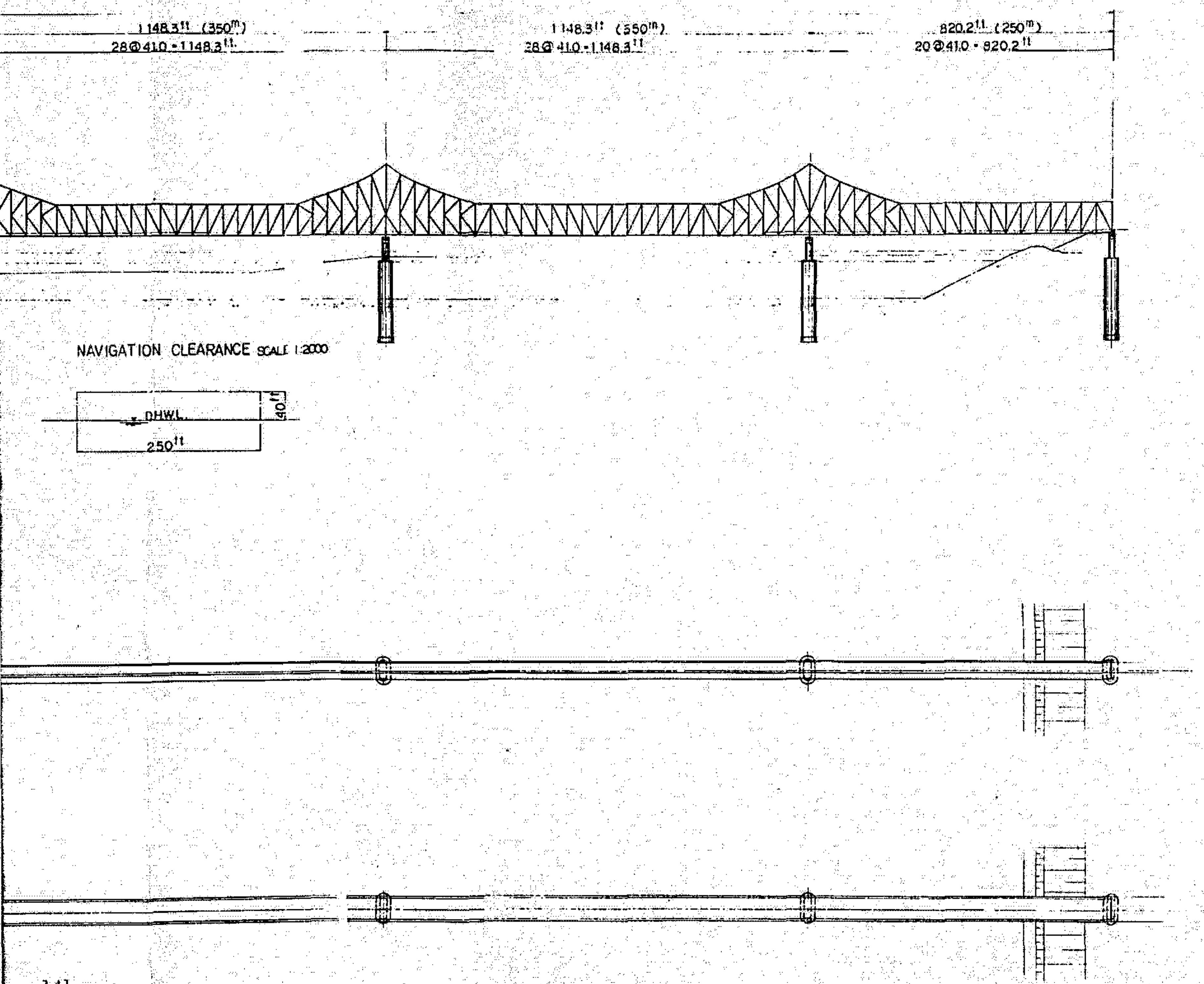
(RAIL - CUM - HEIGHWAY)

CANTILEVER TRUSS

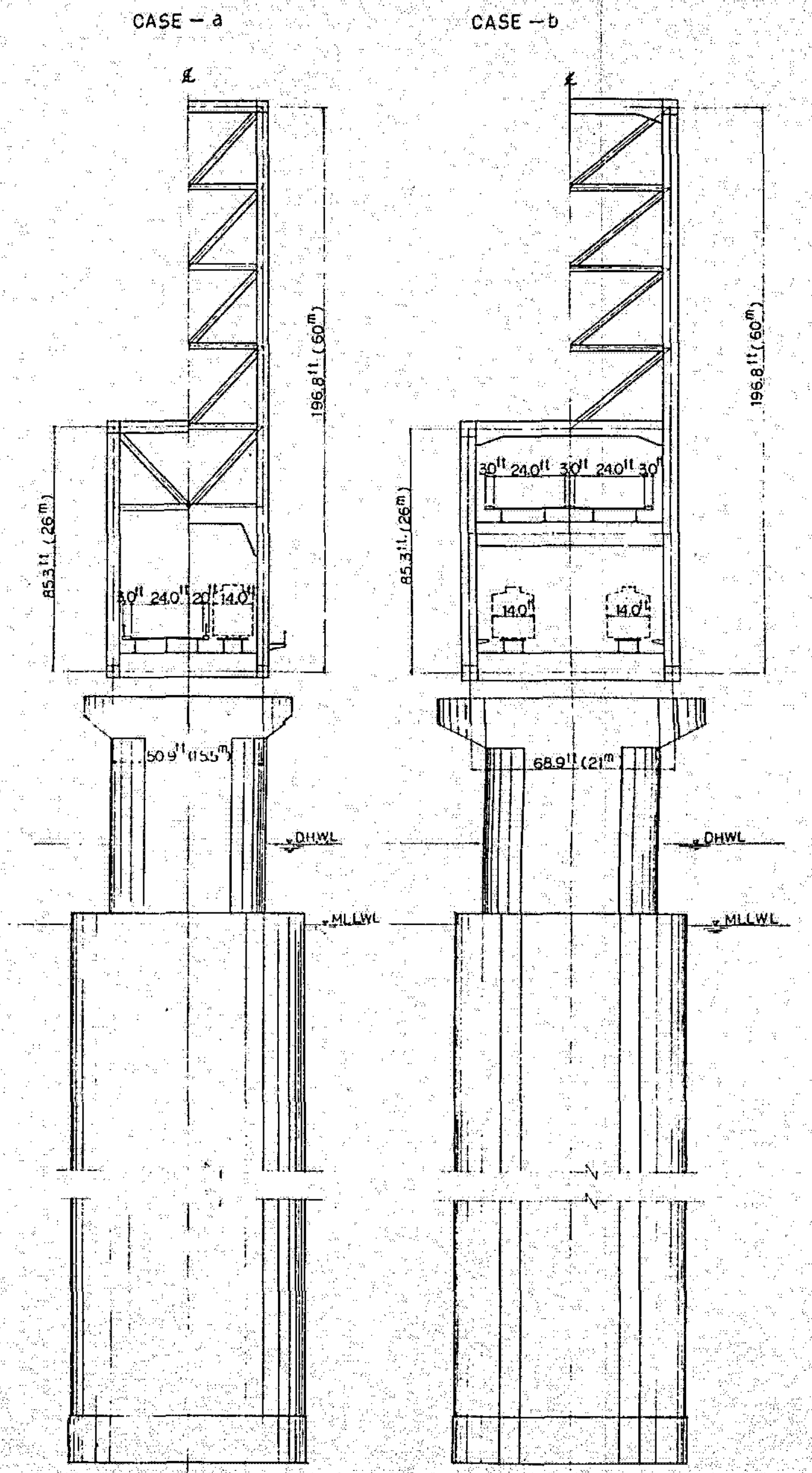
DISTANCE BETWEEN GUIDE BANKS' 2.610 MILE (4.2 KM.)



MUNA RIVER BRIDGE
IGHWAY)
TRUSS
NKS' 2.610 MILE (4.2 KM.)



TYPICAL CROSS SECTION SCALE=1:600



JAPAN INTERNATIONAL COOPERATION AGENCY
PEOPLE'S REPUBLIC OF BANGLADESH
JAMUNA RIVER BRIDGE PROJECT GENERAL VIEW DISTANCE BETWEEN PIERS 1148.3ft
Drawn Date
Approved Date
NIKKEN CONSULTANTS INC. Fig 5-8-4

Table. 5-10-1 Miscellaneous Data of Bridge (≧328ft) in the Domain of Railway Access (in foot)

Name of Site	Name of Bridge	Side of River Bank	Total Bridg Length (ft)	Span Length (ft)	Type of Superstructure	Type of Sub-Structure
1 BAHADURABAD	1 - A	Right	984	9 @ 109	P.C. Simple-G	R.C. Pile
	1 - B	"	656	6 @ 109	"	"
2 GABARGAON	2 - A	Right	328	3 @ 109	"	"
	2 - B	"	328	3 @ 109	"	"
	2 - C	"	492	5 @ 98	"	"
	2 - D	"	328	3 @ 109	"	"
	2 - E	Left	1 312	7 @ 187	P.C. 3-Cont. Box-G	Open Caisson
	2 - F	"	492	7 @ 70	P.C. Simple-G	R.C. Pile
	2 - G	"	492	7 @ 70	"	"
3 SIRAJGANJ	3 - A	"	328	5 @ 66	"	"
	3 - B	"	656	10 @ 66	"	"
	3 - C	"	328	5 @ 66	"	"
	3 - D	"	656	6 @ 109	"	"
	3 - E	"	984	9 @ 109	"	"
	3 - F	"	984	9 @ 109	"	"
4 NAGARBARI	4 - A	Right	328	5 @ 66	"	"
	4 - B	"	656	10 @ 66	"	"
	4 - C	"	1 969	30 @ 66	"	"
	4 - D	"	984	5 @ 197	P.C. 3-Cont. Box-G	Open Caisson
	4 - E	Left	656	10 @ 66	P.C. Simple-G	R.C. Pile
	4 - F	"	3 373	20 @ 169	P.C. 3-Cont. Box-G	Open Caisson
	4 - G	"	328	5 @ 66	P.C. Simple-G	R.C. Pile
	4 - H	"	820	5 @ 164	P.C. 3-Cont. Box-G.	Open Caisson
	4 - I	"	492	3 @ 164	"	"

(note) P.C. : Prestressed Concrete   3-Cont. : 3 Span Continuous

R.C. : Reinforced Concrete   G : Girder

Table. 5-10-2 Miscellaneous Data of Bridge (≧328ft) in the Domain of Highway Access (in foot)

Name of Site	Name of Bridge	Side of River Bank	Total Bridge Length (ft)	Span Length (ft)	Type of Superstructure	Type of Sub-Structure
1 BAHADURABAD	1 - 1	Right	984	9@109	P. C. Simple - G	R.C. Pile
	1 - 2	"	656	6@109	"	"
	1 - 3	Left	328	5@ 66	R. C. Simple - G	"
2 GABARGAON	2 - 1	Right	328	3@109	P. C. Simple - G	"
	2 - 2	"	984	9@109	"	"
	2 - 3	Left	328	5@ 66	R. C. Simple - G	"
	2 - 4	"	1 312	7@187	P.C. 7-Cont. Box - G	Open Caisson
	2 - 5	"	328	5@ 66	R. C. Simple - G	R.C. Pile
3 SIRAJGANJ						
4 NAGARBARI	4 - 1	Right	1 969	10@197	P.C. 3-Cont. Box - G	Open Caisson
	4 - 2	"	984	15@ 66	R. C. Simple - G	R.C. Pile
	4 - 3	Left	656	10 @ 66	"	"
	4 - 4	"	328	5@ 66	"	"

(note) P.C. : Prestressed Concrete

R.C. : Reinforced Concrete

3-Cont : 3 Span Continuous

G. : Girder

5. Properties of Materials and Construction Method.

(1) Properties of materials.

1) Steel materials for the structure.
   Steel materials shown in the Table 5-11 were adopted as standard materials for the structure.
2) Allowable stress of steel materials for structure.
   Allowable stresses of steel materials for structure are as shown in the Table 5-12.
3) Allowable stress of concrete and reinforcement for superstructure.
   Allowable stresses of concrete and reinforcement for superstructure are shown in Table 5-13-1.
4) Allowable stress of concrete and reinforcement for substructure.
   Allowable stresses of concrete and reinforcement for sub-structure are shown in Table 5-13-2.
5) Allowable stress for prestressed concrete structure.
   In superstructure of bridges included to railway access and highway access, prestressed concrete bridge are designed and these allowable stresses are shown in Table 5-14.

(2) Construction method.

1) The Jamuna river bridge.
   Well foundation is generally adopted on land or in river. In the river, island method is used where the water depth is under 16ft. and metallic floating caisson is used where the water depth is above 16 ft.

   In the latter case, it is desirable for execution that steel floating caisson is carried to the site and sunk it depositing the concrete in the hollow part of it.

   In well construction, it is the geral rule principle to finish the whole work during a dry season.

   Thereafter upper slab of well shall be concreted and body of pier is constructed up to the proper height, therefore the level of upper surface of island must be kept up to the height above water level at the beginning or end of wet season.

   In the same way the proper island is also necessary for land work.

Table.5-11 Standard Specification of Steel Materials.

Standard		Symbol of Steel Materials
JISG 3101	rolled steel for general structure	SS 41
JISG 3106	rolled steel for welded structure	SM41, SM50Y SM53, SM58

Table.5-12 Allowable stresses of steel Materials for Structure (psi)

Steel material / Stress	SS 41, SM41	SM50Y, SM53	SM58
Axial tensile stresses	19912	29 868	36 980

Table. 5-13-1 Allowable Stress of Materials for Superstructure of Reinforced Concrete.

Design Strength of Concrete σck					3 400
Allowable Stress (Psi)	Concrete	Bending Compressive Stress			1 140
		Compressive Stress by Normal Force			1 020
		Shearing Stress	In case of to be resisted by concrete only	Slab	130
				Beam	100
			In case of using web reinforcement		280
		Bond Stress			220
		Bearing Stress			1 020
	Reinforcing Bar	Tensile Stress		SD 30	25 600
		Yield Stress		SD 30	42 700

Table. 5-13-2 Allowable Stress of Materials for Substructure of Reinforced Concrete.

Design Strength of Concrete σck					3 000
Allowable Stress (Psi)	Concrete	Bending Compressive Stress			1 000
		Compressive Stress by Nomal Force			900
		Shearing Stress	In case of to be resisted by concrete only	Slab	120
				Beam	92
			In case of using web reinforcement		260
		Bond Stress			210
		Bearing Stress			900
	Reinforcing Bar	Tensile Stress SD 30		Usually	25 600
				In Water	22 700
		Yield stress		SD30	42 700

Table. 5-14 Miscellaneous Values for Superstructure of Prestressed Concrete

Material	Descriptions		Values
Concrete	Design Strength	σ_{ck}	5 000 PSI
	Acting Design Load (Compressive Stress)		1 660 "
	" (Tensile Stress)		190 "
	Strength at Prestressing		4 300 "
	Maximum Size of Coarse Aggregate		1 inch
Prestressing Wire ø 7mm	Breaking Stress		220 KSI
	Yield Stress		192 "
	Allowable Tensile Stress	Design Load	132 "
		at Prestressing	173 "

In order to complete such a work during a short period, it is desirable to apply the reverse circulation method which is performed by the special construction machinery. The machinery consists of reverse circulation drill and driving facilities.

As for the erection of superstructure, stage erection shall be applied for the place where the depth of water is samll and cantilever erection shall be applied for the place where the depth of water is large.

It is desirable to erect a large block of members of bridge at a time for the place where the depth of water is large but the velocity of flow is small or for the other suitable places on land. In this way, we can reduce the period of erection.

6. Construction Cost for Bridge Works.

General construction cost for bridge works of this project was roughly estimated according to the following conditions.

a. The cost was counted by the unit prices in March 1974.
b. Depreciation of main construction machineries is finished during the working period.
c. Unit prices of basic materials for construction are as follows.

Structural steel	2,200 TK/t (in Japan)
Deformed bar	3,000 TK/t (at site)
Heavy(regular) sheet pile	1,610 TK/t (in Japan)
Light sheet pile	1,720 TK/t (in Japan)
Cement	440 TK/t (at site)
Sand for concrete	450 TK/100cft (at site)
Gravel	800 TK/100cft (at site)

In above estimation, system of width of bridge consists of single broad gauge(5' 6") and 24 ft two-lane carriage-way.

The following costs are excluded from the total of the Table 5-15.

Cost for administration and engineering,
Cost for general facilities for construction and
Contingencies.

Table 5-15 Rough Estimate of Bridge Construction Costs

(x 10^6 in TAKA)

Type of Bridge Width	Site Proposed for Bridge Const.	Distance btw. Guide Banks	Super Structure	Sub-Structure	Approach Road	Subtotal	Transportation Cost	Total
Two lanes, Single track (Single Deck Type)	Bahadurabad	2.6 miles	750	840	390	1 980	250	2 230
		3.5 "	960	1 100	400	2 460	330	2 790
	Gabargaon	2.6 "	750	840	390	1 980	250	2 230
		3.2 "	880	1 050	410	2 340	290	2630
	Sirajganj	2.6 "	750	820	410	1 980	250	2 230
		3.5 "	960	1 070	440	2 470	330	2800
	Nagarbari	2.6 "	750	900	490	2 140	250	2 390
		3.2 "	880	1 080	510	2 470	290	2 760

ANNEX-1 Contents of Accumulated Data

NO	DATA	SOURCE	GIVEN LENT BUY	REMARKS
1	Roads and Highways Directnate Schedule of Rate for Construction of BRIDGE	Road & Highways M.O.C.	Given	
2	Roads and Highways Directnate Schedule of Rate for Road Works	"	"	
3	Monthly Rainfall Statement on Sirajganj at 1973.		"	
4	Daily Report Sheets MITSUI-OHBAYASHI J.V.	OHBAYASHI Office	"	
5	Report of the National Pay Commission		Buy	
6	Plan and Profile of Dacca-Aricha Highway Bridge. Mirpur Br. Bangshi Br. Kaliganga Br.	R.&H. M.O.C.	Given	
7	Sinking Record of Caisson of KALIGANGA Br.	"	"	
8	Sinking Report of No.4 Caisson of Sitarakya Br.	OHBAYASHI office	"	
9	Road Map of Bangladesh scale 1 inch=8 miles	R & H M.O.C.	"	
10	Bangladesh Land & People		Buy	
11	1st 5 years Plan		"	
12	General Rules and Schedules for Working of the Chittagong Port (Railway) from January 1959	Chittagong Port Trust	Buy	
13	Manual of Standard Bridge Design (East Pakistan)		"	
14	Power Development in Bangladesh		Given	
15	Law of Evidence & Limitation		Buy	
16	Constitutional Law in Bangladesh		"	
17	Law of Tort		"	
18	Interim Report on Remedial Works Required to Harding Bridge & King George V Br.	Jamuna Br, Survey Office	Given	

NO	DATA	SOURCE	GIVEN LENT BUY	REMARKS
19	Re-Openning of King George V Bridge over the Meghna	Jamuna Br. Survey Of.	Given	
20	The Harding Bridge over the Lower Ganges at Sara	Bangladesh Railway (Paksey)	"	
21	Modorn Road Construction Procedures	R&H,M.O.C.	"	
22	Bangladesh Consultants Limited		"	Consulting Firm
23	Associated Consulting Engineers Ltd.		"	"
24	Prachi Prakaushali Sangstha Limited		"	"
25	Prakaushali Sangsad Limited		"	"
26	M essrs Rahman & Associated Ltd.		"	"
27	Engineering Consultants & Associated Ltd.		"	"
28	Brixton & Brixton Ltd. Consulting Engineers		"	"
29	Bureau of Consulting Engineers LTD.		"	"
30	Associated Architects and Engineers Ltd.		"	"
31	Bangladesh Survey Organization Ltd.		"	Land Survey
32	The Engineers Ltd.		"	Construction Firm
33	Bengal Development Corporation Ltd.		"	"
34	Stonevill Engineers Ltd.		"	"
35	National Builders & Engineers Ltd.		"	"
36	Delta Constructions Ltd.		"	"
37	Harding Bridge-Section of Scouring Taken at Centre Line from July to December 1973	Bridge Engineer, West Paksey	"	

ANNEX-2

BANGLADESH RAILWAY.

No.XEN/J/G/74. Dated:- 28 - 1 - 1974.

From:- XEN/J.B.S/Dacca. To:- The Director,
Jamuna Bridge Survey/DA.

Sub:- Confirmation of Datas.

Mr.Tezuka,Leader of Bridge Planning Team wanted confirmation of the following datas in connection with designing of Bridge Girders of proposed Jamuna Bridge.

1. Bridge Girders to be designed as per Main Line loading of Indian Railway Bridge Code.

2. All structures to be designed keeping the provision of Electrification in future.

The above Datas are hereby confirmed.

Executive Engineer,
Jamuna Bridge Survey,
Bangladesh Railway,Dacca.

Copy to ENC/CRB for information. Since the Team wanted the confirmation of the above Datas by 31.1.74,so the undersigned confirmed the above Datas on behalf of Bangladesh Railway.

Sd/-

Executive Engineer,
Jamuna Bridge Survey,
Bangladesh Railway, Dacca.

ANNEX-3

Grams : AUTHORITY
Phones : 245251 - 55

বাংলাদেশ আভ্যন্তরীণ নৌ-পরিবহন কর্তৃপক্ষ
BANGLADESH INLAND WATER TRANSPORT AUTHORITY

ডি, আই, টি, ভবন (শাখা)
পোষ্ট বক্স ৭৬, ঢাকা-২
বাংলাদেশ

DIT BUILDING (ANNEXE)
POST BOX 76, DACCA-2
BANGLADESH

Memo.No.CE/JB/J-AID/ 3460 Dated: ~~January~~ Feb 5, 1974.

Mr. Junji Ebihara,
Director, Jamuna Bridge Survey Office,
783, Dhanmondi R.A., Road No.19,
Dacca-5.

Sub : Jamuna Bridge - Minimum horizontal and vertical clearances to meet navigational requirements.

Ref : Your letter No.BIWTA-II/341/74 dated 20.1.74 addressed to Chairman, BIWTA.

Dear Sir,

The undersigned is directed to refer to your above mentioned letter addressed to Chairman, BIWTA and to inform that the following are the minimum navigational requirements in so far as the proposed rail-cum-road bridge across the Jamuna is concerned:

1. Minimum horizontal clearance between two piers ... 250(two hundred and fifty) feet.

2. Minimum vertical clearance under the soffit of the girders ... 40 (forty) feet.

(Anwar Hossain)
Secretary.

Dated: ~~January~~ Feb 5, 1974.

CHAPTER VI

STUDY OF ACCESS RAILWAY

1. General .

The purpose of the study included in the Jamuna River Bridge Construction Project is to provide the optimum planning of the access rialway line connecting the existing railway to the bridge site in oder that the proposed Jamuna bridge would discharge the high functions of a railway bridge across Jamuna River which divides the country into the east and the west regions.

Through the four alternative bridge sites:

No. 1: Bahadurabad

No. 2: Gabargaon

No. 3: Sirjganj, and

No. 4: Nagarbari

Four railway links connecting the east and the west regions have been elaborated. Each route is to examined from the point of location, structure specifications, alignment, length, number of structures, transportation volume, railway operations and safety, relationship with the future plans of Bangladesh Railway and construction cost.

The study work in the first stage, for the railway sector covers the selection of the optimum access railway based upon the priority ratings of the four access railway links, providing all necessary data for dtermining the optimum brige site.

2. Site Investigation .

The Railway Team stayed in Bangladesh about 40 days from the middle of January 1974 and made a precise investigation of the railway sections of Bangladesh Railway relevent to the Jamuna bridge project.

The track and structure of the railway systems were found to be generally poor and the maintenance scarce. Especially in the station, the main track lines and side track lines were in very bad condition and maintenance was poor. From the point of view of operation and safety, there were many undesirable track layouts such as double slip switch.

The Team visited the transhipment yard of Santahar Station where they found the facilities not fully operated and a considerable part idle. Most of the lines including broad and metre gauge are of single track and seem to have sufficient carrying capacity. The Team judged that, with the possible increase of transportaiton volume in the future the train frequency of more than 100 in two way directions could be maintained if an automatic signal device for single track and well located through-type stations were provided.

The introduction of the CTC (centralized traffic control) system which integrates the operation instruction and the signal handling will contribute to the modernization of railway transportation.

Railway electrification will bear full fruit in the reinforcement of transportation and the modernization of motive power. Fortunately this country is expected to have abundant natural gas resources. With the development of thermal power generation, railway electrification which produces high efficiency in motive power will be hopefully promoted.

3. Planning of Access Railway.

a. Gauge.

The Jamuna river line demarcates the area of the broad gauge (5' - 6") in the west from the region of metre gauge (1.000 m)to the east with a few exceptions to the broad gauge in the west. The connecting operation of metre and broad gauge lines takes place in the transhipment yard of Santahar Station.

With the completion of the Jamuna bridge, the two railway networks in the east and the west will be integrated into one single network. The problem of selecting the size of the gauge for the access railway arose but the broad guage track has been decided for the study of all the four access railways, taking inot account the future improvement plans of Bangladesh Railway.

No new transhipment facilities shall be provided for this access railway study on the assumption that a uniform gauge line from North Bengal through to Dacca will be constructed by the Government in the future.

The access railways of No. 1 and No. 2 routes originate from Santahar Station with a broad gauge line, crossing Jamuna River and terminate at the respective stations on the nearest existing metre gauge line from the river. The planning of these access railways should be incorporated into the future plans of Bangladesh Railway in order to maintain speedy transportation without the trouble of transhipment.

The access railways of No. 3 and No. 4 routes diverge from the existing broad gauge line in the west and terminate at Dacca with a broad gauge line. There is no problem of transhipment through to Dacca.

b. Fixed Points.

The starting point (00 km 000 m) of each access railway shall be at the center of the proposed connecting station of the existing railway line on the right side of Jamuna River and the terminating point at the center of the connecting station of the proposed existing railway line on the opposite bank side.

c. Length.

The length of the access railway shall be the overall length from the starting point to the terminating point, including the bridge sections. In the case of the study of No. 1 and No. 2 routes where the construction of the new broad gauge line alongside the existing metre gauge is regarded as necessary, the length of the required broad gauge line shall be indicated separately.

However, for the estimation of the construction cost of each access railway, the earthwork and land acquisition of the bridge proper and the graded approach section to the Jamuna bridge shall be excluded in this study but included in CHAPTER V STUDY OF BRIDGE WORKS.

d. Level.

The G.T.S. unit is used for the altitude throughout the profile design work:

G.T.S. = P.W.D. - 1.5 ft

e. Gradient and Curve.

The maximum gradient for the access railway is 1 in 200, and the minim curve radius 1,000 metres.

The length of the graded approach sections to the Jamuna bridge will be several kilometers. A flatter gradient is to be adopted for the Jamuna river sections only, according to the request of the Bangladesh Government at the Tokyo meeting.

The railway Team consider that the provision of the gradient 1 in 200 would be more desirable from the economical point of view, as it is envisaged that the recruited locomotives of the country will give better performance in the future and that the gradient will not greatly affect train operation.

However, in the second stage, the provision of flatter gradients 1 in 300 and 400 will be elaborated, based on the study of locations of through-type stations resulting from the predicted future traffic volume.

f. Track.

Meeting the estimated Traffic volume for 50-years future by the traffic study, the railway team has evaluated the carrying capacity of the line for the volume. It can be envisaged that even single track transportation would meet the future needs across Jamuna River.

However, if the traffic study reveals the necessity of dobule track in later years, the provision of through-type stations with easy reduction of the distance between stations and of double track from the proposed single track can be easily kept for the sections of the access railway except the section of Jamuna River which is much longer than the others. For these sections the carrying capacity can be easily reinforced.

On the other hand, however, it will be very difficult to improve the river section in later years in order to increase the carrying capacity to meet increasing transportation demands. It is therefore necessary to keep the cross-sectional space for the future provision of double track on the bridge.

As such a provision requires a huge amount of initial cost, careful overall consideration is to be given to other fields of the project study, when future traffic has finally been predicted. This problem will be studied in the second stage after selection of the optimum bridge site.

g. Signalling.

The information concerning the train operations in the specified operation sections is concentrated into the single control office and indicated for the implementation of speedy and accurate instructions. The centralized traffic control (CTC) system will be adopted for this study in oder to directly control the direction of the trains in the station and to integrate train instruction and signal handling.

Manual signalling will be sufficient for the near future since railway modernization has not been greatly developed. The time will come when provision of the CTC system will be ncessary for the future development of the railway modernization of the country. A rough estimate for the CTC device will be included in the construction cost.

4. Specifications of Railway Design.

Based on the guideline to the railway planning in the preceeding section, design specifications of the new railway line have been studied and the summary of the main criteria to be adopted for the study is as follows:

Gauge:	broad
Track:	single
Gradient:	maximum = 1 in 200 (for short distance onl
Top of fill sub-grade:	over 3' - 00" above H.W.L.
Width of fill sub-grade:	20' - 00"
Design load:	axial load of 22.5 tons based on Broad Gauge Standard Loading of 1926.(Ref. Fig.
Track structure:	90 lb/yard (= 50 kg/m) rail, wood sleeper and (1375 pcs/km) ballast base
Train speed:	maximum = 96 km/hour (60 miles/h.) average = app. 54 km/hour (34 miles/h.)
Typical cross-section of earthwork:	Ref. Fig. 6-2 in attached sheet
Typical cross-section of track structure:	Ref. Fig. 6-3 in attached sheet
Signalling:	Centralized Traffic Control (CTC)

Details of specifications will conform to the "Code of Practice for Engineering Department of Bangladesh Railway".

Fig. 6-1 BROAD GAUGE STANDARD LOADINGS OF 1926

AXIAL LOAD OF 22.5 TONS

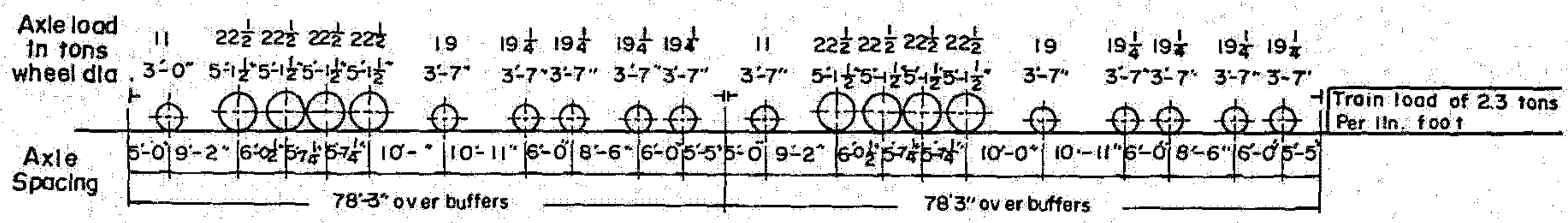
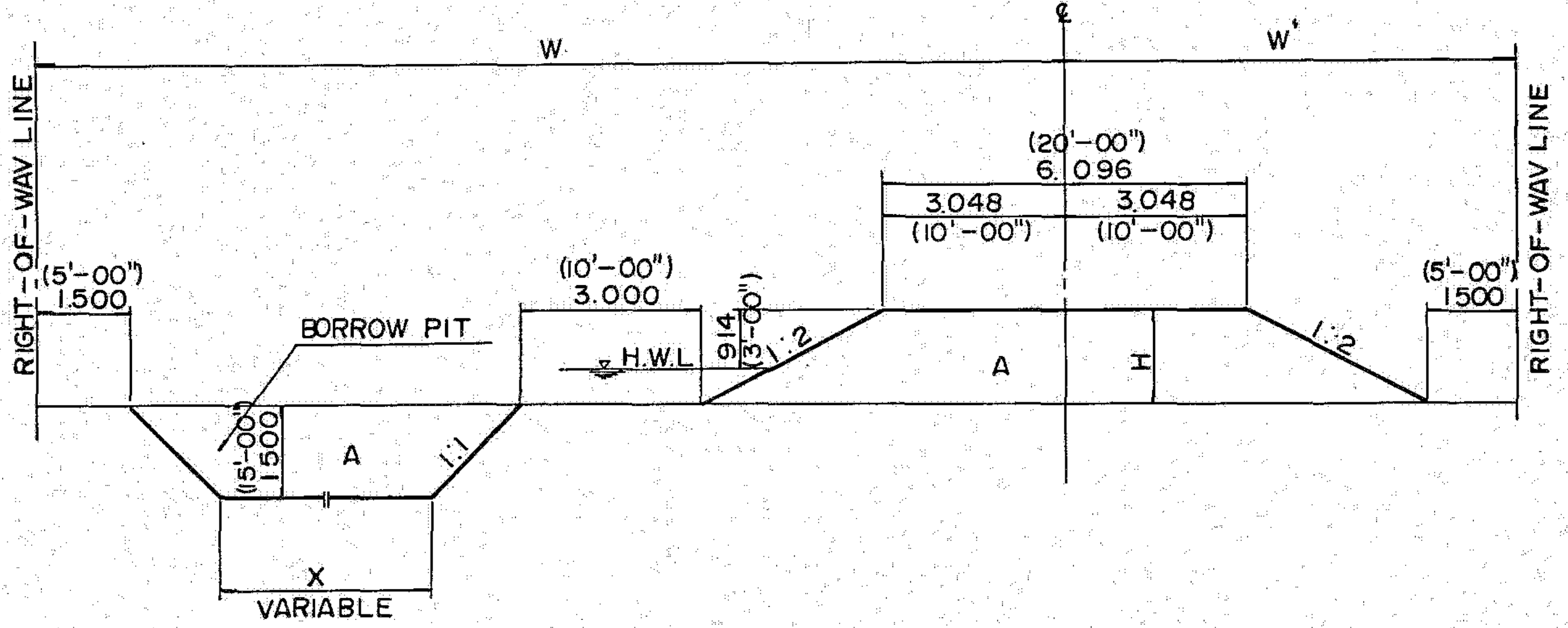


Fig. 6-2 TYPICAL CROS-SECTION OF RAIL WAY EARTHWORK

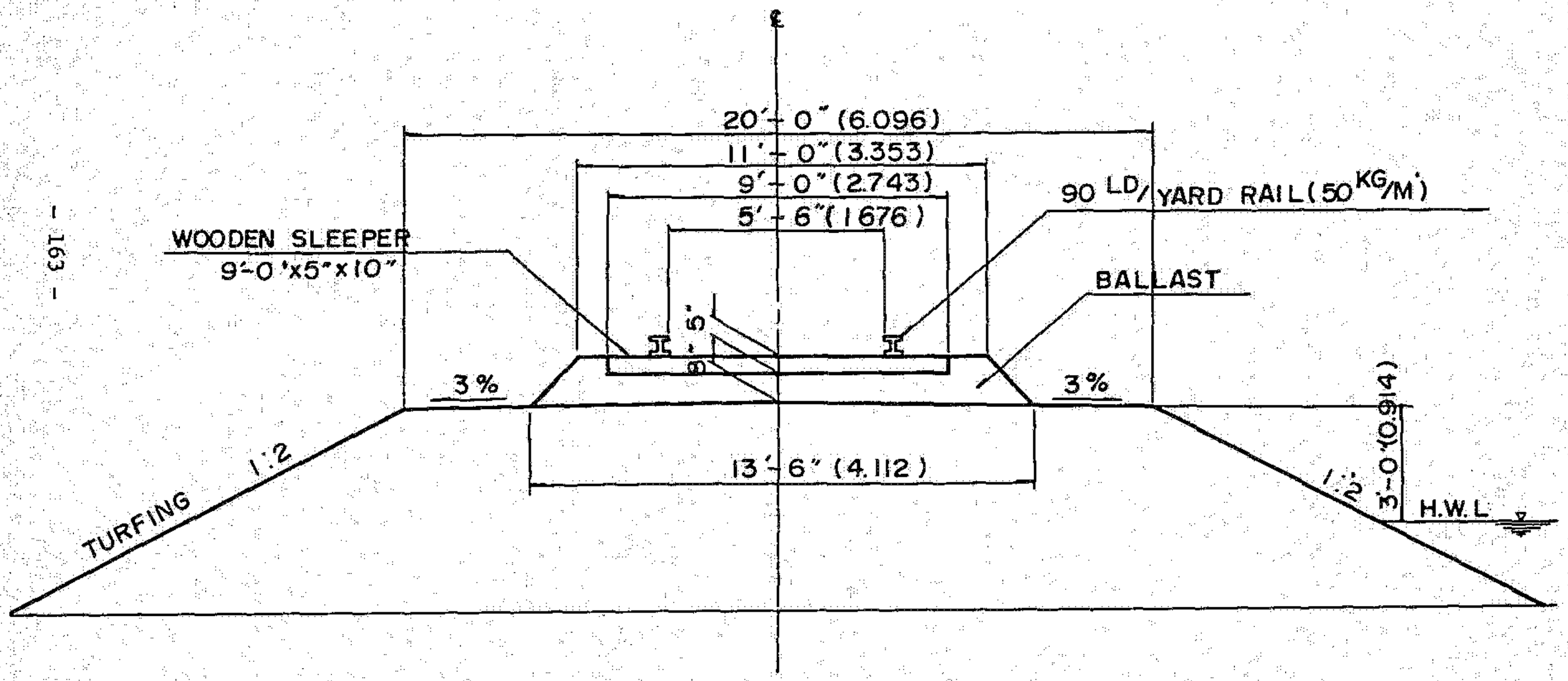
Scale 1/100



RIGHT-OF-WAY = W + W'

Fig. 6-3 TYPICAL CROS-SECTION OF RAILWAY TRACK

SCALE 1/50



5. Route Location.

1) No. 1 route (Bahadurabad).

This is the northernmost line among the four access railways. The route is about 38 km (24 miles) long, diverging from Velurpara Station on the existing Santahar - Bonarpara line (metre gauge) on the right side of Jamuna River, running eastward parallel to the existing line about 4 km, crossing Bangali River after turning to the right, and reaching the Jamuna Bridge at point 17 km. The route continues almost straight as far as point 32 km and terminates at Durmut Station on the existing Bahadurabad - Jamalpur line (meter gauge) on the left side of the river.

Since the proposed link is a broad gauge line, it will be necessary in the future to lay a broad gauge line from Durmat through to Dacca via Jamalpur. However, this gauge widening project shall be left to the future improvement plans of the Bangladesh Railway and in this comparative study of the routes, Durmat will be the terminating station. The existing line on the right side is also of metre gauge and a broad gauge line is to be constructed alongside the existing metre gauge line from Velurpara Station through to Santahar Station. The required length is about 62 km (39 miles).

2) No. 2 route (Gabargaon).

This route diverges from Bogra Station on the existing Santahar - Bonarpara line (metre gauge) on the right side of Jamuna River, crossing Karatoya River, turning to the east at point 3 km and running straight as far as point 20 km and reaches the Jamuna bridge at point 30 km after crossing Bangali River.

As point 48 km the route crosses Jhinai River, turning to the left at point 54 km and terminates at Jafar Shafee Station on the existing Jamalpur - Jagannathganj line (metre gauge) on the left side, with a total track length of about 55 km (34 miles).

As in the case of No. 1 route, the proposed bridge site of No. 2 route is very near to the existing metre gauge line on either side of Jamunar River and the provision of transhipment facilities of metre and broad gauge lines would be required without gauge widening of the existing lines.

Smooth and speedy movement of goods between the east and the west regions is one of the fundamental purposes of the Jamuna River Bridge Construction Project. The provision of transhipment facilities will not be desirable from the point of view of railway operations. Therefore, a uniform gauge line shall be provided form North Bengal through to Dacca with no provision of transhipment facilities.

On the right side, a broad gauge line shall be constructed alongside the existing metre gauge line from Bogra through to Santahar. On the left side, the terminating station shall be Jafar Shafee where Bangladesh Railway would take over the broad gauge line through to Dacca in future.

3) No. 3 route (Sirajganj).

This route diverges from Salap Station on the existing Ishurdi - Sirajganj line (broad gauge), running eastward and reaches Jamuna River at point 13 km after crossing Harasagar River.
And also, it reaches Dhaleswari River at point 23 km, reaching Tangail at point 42 km after running southward. But this river is belockaded by the highway embankment. A new station is to be built at Tangail.

The route runs further down south, turning to the east after crossing Futjani River and at point 67 km it reaches Mirzapur. The route proceeds eastward, appraching the existing main hihgway and at point 96 km it crosses Turag River after reaching Kaliakair. The route runs southward and terminates at the proposed Azampur Station after crossing Tungi River. The new station is to be built on the existing railway line between Dacca and Tungi, to the north of the proposed airport complex. The total track length is about 114 km (71 miles).

According to the plans of the Government, a broad gauge line will be constructed from Azampur through to Dacca and a transhipment yard provided at New Dacca Station (Kamalpur). With this route broad gauge line transportation would be maintained from North Bengal through to Dacca.

4) No. 4 route (Nagarbari).

This is the southernmost line among the four access railways. The route diverges from Gooakhara Station on the existing Ishurdi - Sirajganj line (broad gauge) on the right bank, running almost straight as far as point 30 km after turning to the right and crosses Baral

River, reaching Jamuna River at point 41 km. The route crosses Dhaleswari River at point 70 km and runs eastward, crossing Turag River, and terminating at Azampur between Dacca and Tungi. The location of Azampur Station and the connection system through to Dacca are similar to No. 3 route. The total track length is about 120 km (75 miles), the longest line among the four access railways.

6. Construction Cost.

The comparison of the rough construction cost of the four access railways has been shown below.

No. 1 route is the most economical, followed by No. 2 route. For transportation without transhipment facilities through to Dacca, gauge widening improvement is to be implemented from the respective terminating stations through to Tungi (Azampur) via Jamalpur and Mymensingh.

The length of the widening imporvement to broad gauge amounts to 124 km for both No. 1 and No. 2 routes and the widening cost can be roughly estimated at:

4,000,000 taka/km · 124 km = 496,000,000 taka

assuming the widening cost per kilometre be a half of the normal construction cost.

Therefore, No. 3 route is the most economical, if the future railway network of the country is to be considered.

<u>Rough Cost Comparison</u> Cost (1,000 taka)

Route	New Construction	Gauge widening	Total	Priority order
No. 1	727,000	496,000	1,223,000	3
No. 2	727,000	496,000	1,223,000	3
No. 3	884,000	---	884,000	1
No. 4	1,003,000	---	1,003,000	2

Rough Construction Cost of Access Railways

Item	Unit	No. 1 Route Bahadurabad	No. 2 Route Gabragaon	No. 3 Route Sirajganj	No. 4 Route Nagarbari	Remarks
Earthwork	1,000 TAKA	207,000	238,000	270,000	320,000	includes land acquisition
	1,000 YEN	(7,460,000)	(8,560,000)	(9,720,000)	(11,500,000)	
Bridge and Culverts	1,000 TAKA	78,000	73,000	99,000	153,000	includes spillway
	1,000 YEN	(2,840,000	(2,650,000)	(3,600,000)	(5,620,000)	
Track laying	1,000 TAKA	244,000	227,000	273,000	280,000	
	1,000 YEN	(8,850,000)	(8,240,000)	(9,920,000)	(10,220,000)	
Operation facilities	1,000 TAKA	198,000	189,000	242,000	250,000	include Stations, lighting, power, telecommunication, signalling, acommodation and other buildings
	1,000 YEN	(7,150,000)	(6,750,000)	(8,760,000)	(8,960,000)	
Total	1,000 TAKA	727,000	727,000	884,000	1,003,000	
	1,000 YEN	(26,300,000)	(26,200,000)	(32,000,000)	(36,300,000)	
Total route length	Mile	63	59	71	75	
	Km	(100)	(95)	(114)	(120)	

APPENDIX "A"

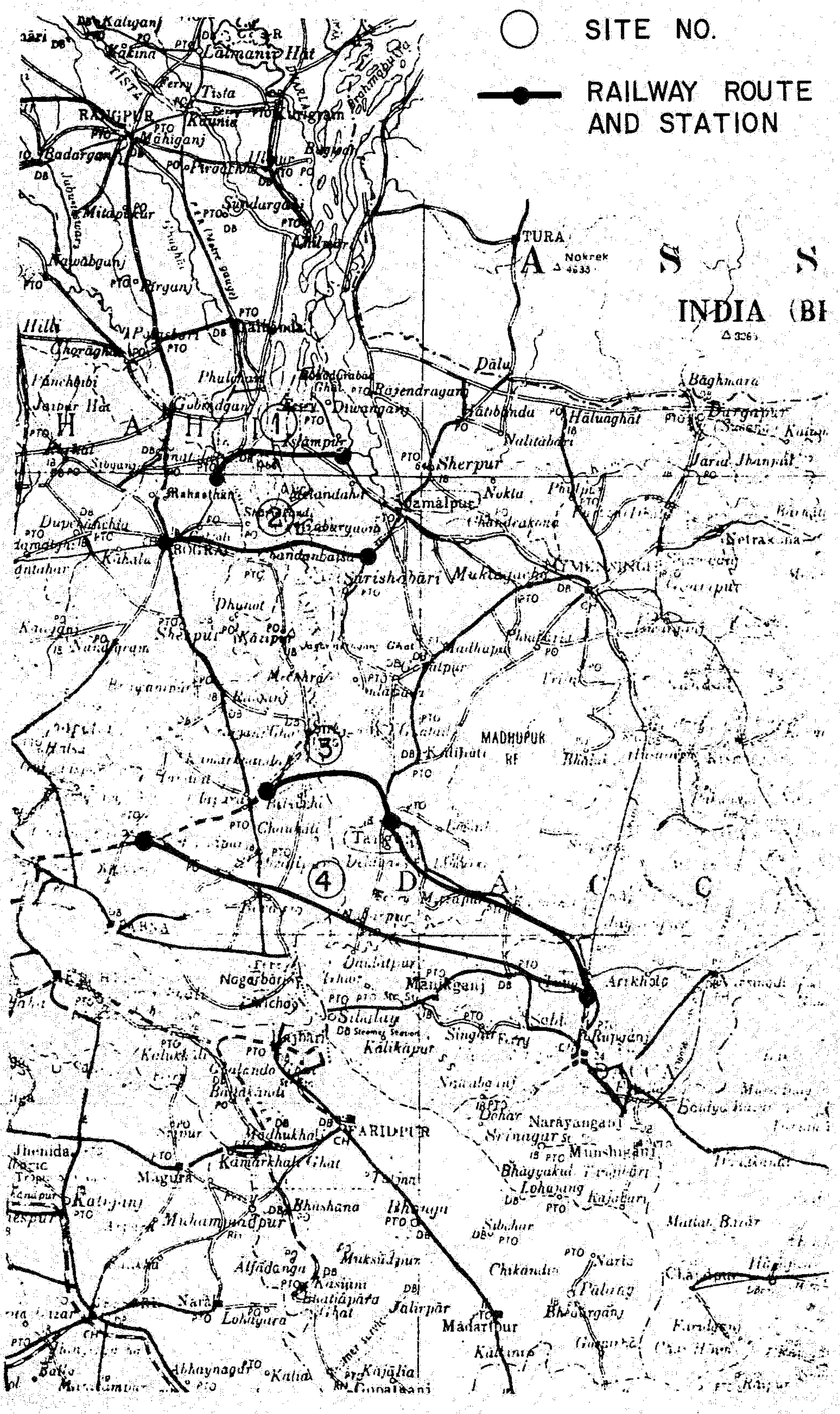
Summary of Railway Approach Lines

(Table)

SUMMARY OF ACCESS RAILWAY LINES

Site Number & Nomination		No. 1 Bahadurabad	No. 2 Gabargaon	No. 3 Sirajganj	No. 4 Nagarbari
Originating Station and its Location		Velurpara on Santahar - Bonarpara Line	Bogra on Santahar - Bonarpara Line	Salap on Ishurdi - Sirajganj Line	Gooakhara on Ishurdi - Sirajganj Line
Terminating Station and its Location		Durmat on Jamalpur - Bahadurabad Line	Jafar Shafee on Jamalpur - Jagannathganj Line	Azampur (or Tungi) on Dacca - Tungi Line	Azampur (or Tungi) on Dacca - Tungi Line
Total Length of Line (Km)		38 (24 miles)	55 (34 miles)	114 (71 miles)	120 (75 miles)
Gauge		Broad (5' - 6") 1,676 m	Broad (5' - 6") 1,676 m	Broad (5' - 6") 1,676 m	Broad (5' - 6") 1,676 m
Number of Tracks		Single	Single	Single	Single
Major Station		—	—	Tangail Station	—
Number of Minor Stations		3	5	11	12
Allowable Maximum Gradient		5/1,000	5/1,000	5/1,000	5/1,000
Minimum Curve (meters)		R=1,000	R=1,000	R=1,000	R=1,000
Bridge Running Length (m)	Class A: L > 100 m	500 (1640[f])	1,050 (3,450[f])	1,300 (4,270[f])	3,050 (10,000[f])
	Class B: L < 100 m	270 (890[f])	180 (590[f])	360 (1,180[f])	360 (1,180[f])
Earthwork up to Formation (m^3)		2,100,000	3,300,000	5,400,000	6,400,000
Area of Land Acquisition (m2)		2,400,000	3,500,000	6,400,000	7,200,000
Length of New Broad Gauge Line alongside the Existing Meter Gauge		62 km (39 miles) Station: Velurpara to Santahar	40 km (25 miles) Station: Bogra to Santahar	—	—

BANGLADESH
SHOWING COMMUNICATIONS



1967
Scale 1:1,000,000 (1 Inch to 15.783 miles)

Miles 10 0 10 20 30 40 50 60 70 80 90 Miles

Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 Kilometres

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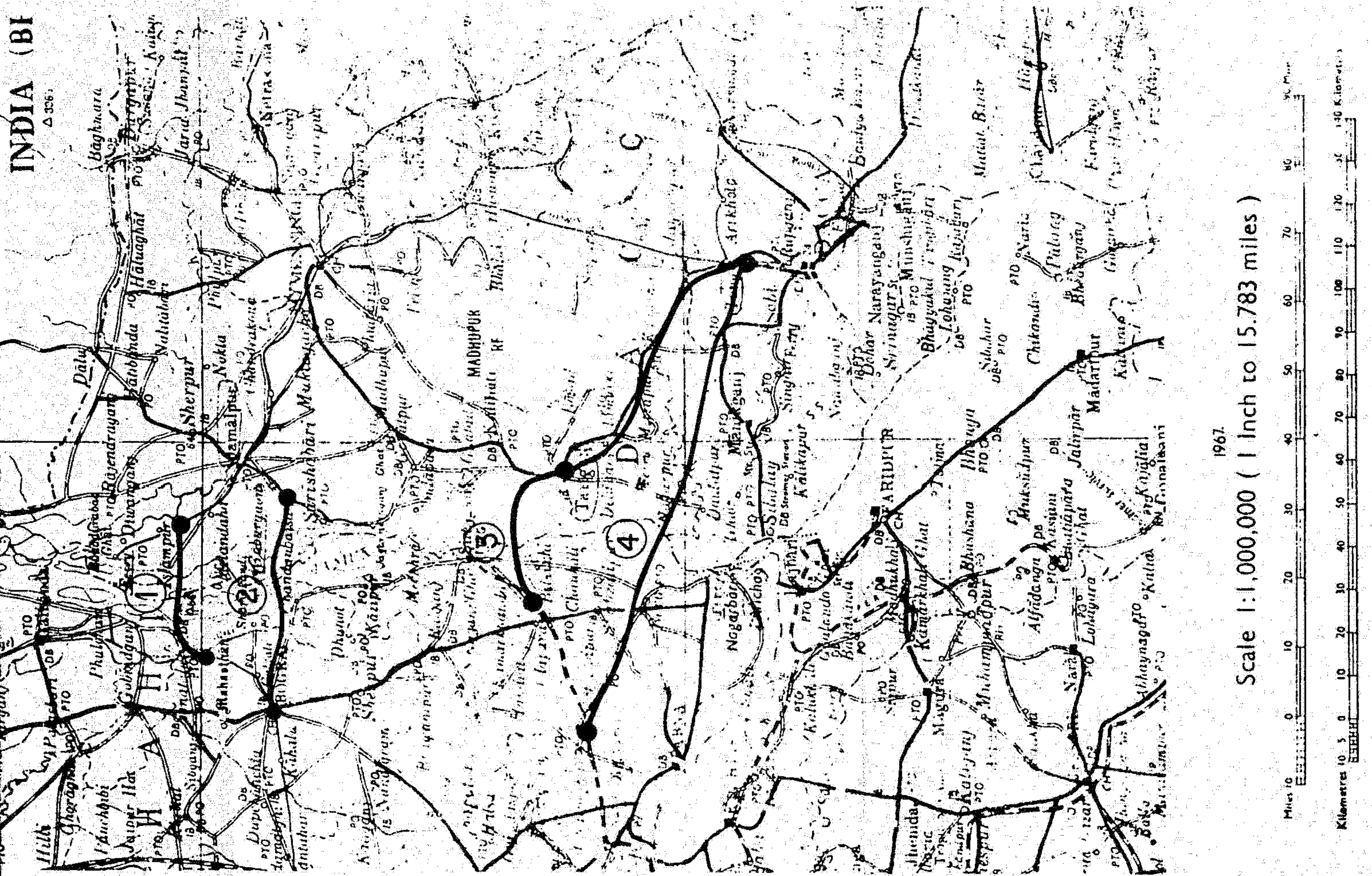

G.T.S. DATUM LEVEL

JAPAN INTERNATIONAL COOPERATION AGENCY	
PEOPLE S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE PROJECT **GENERAL PLAN OF RAILWAY APPROACH LINES** SCALE : 1/1000 000	
Drawn	Date
Approved	Date
PACIFIC CONSULTANTS INTERNATIONAL	Fig 6-4