CHAPTER VI

SCOUR AT BRIDGE PIERS

1. Studies on Depth of Scour at Bridge Piers.

P. Andru (124 GB) has obtained the following formula expressing the relation among scoured depth, bed factor Q^2/B^2H^3 and unit discharge on the basis of field measurements and model tests.

$$H_s(Q^2/B^2H^3)^{1/3} = 1.8(Q/B)^{2/3} \qquad (6.1)$$

or

$$H_s = 1.8\ H$$

where
- H_s = scoured depth measured downwards from the water surface
- Q = discharge
- B = width of wide rectangular channel
- H = water depth.

On the other hand, E.M. Laursen has obtained the following formula on the basis of extensive experiments (123 GB).

$$H_s = H + d_s \times k_s \times k_\alpha \times k_\tau \qquad (6.2)$$

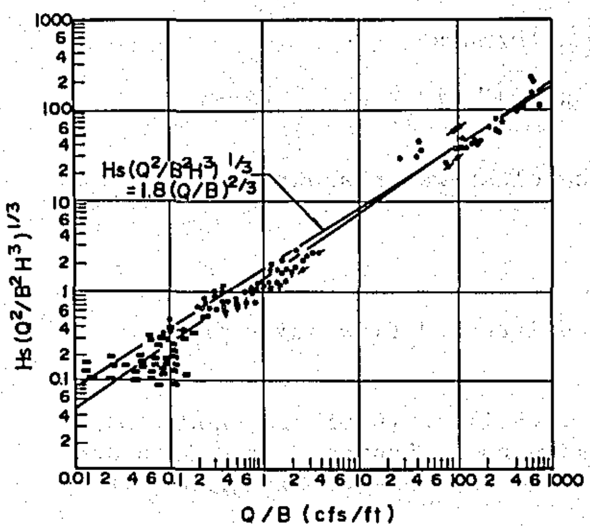
where
- d_s = scoured depth measured downwards from the river bed before scour; the relation between H/b and d_s/b is given in Fig. 6-2-1,
- b = width of a pier,
- k_s = shape coefficient for nose forms to be used only for piers aligned with flow; Fig. 6-2-2 is prepared,
- k_α = multiplying factor to be applied to the depth of scour obtained from the basic curve; a family of curves for α, L/b and k_α is prepared in Fig. 6-2-3,
- = angle of attack between the pier and the flow,
- L = length of a pier in the direction of the flow,
- k_τ = ratio of depth of scour under suspended-load conditions to depth of scour under bed-load conditions; curves for d_s/H, u_*/w_o and k_τ are prepared in Fig. 6-2-4;
  $k = 1$ in the case of $u_*/w_o < 1/2$,
- u_* = friction velocity,
- w_o = settling velocity of sediment particle.

According to the study made by Breusers (133 GB), the equilibrium depth of scour with continuous sediment motion is given by

$$d_s = 1.4\ b \qquad (6.3)$$

for circular cylindrical piers. On the other hand, Larras (134 GB) found that

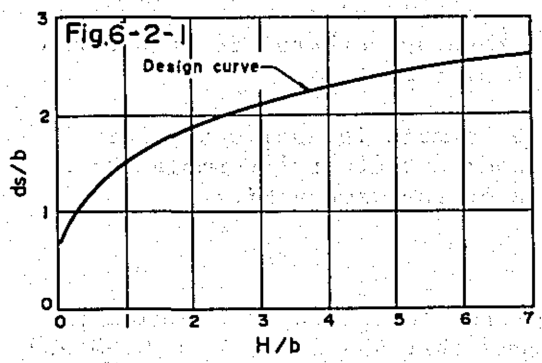
Fig. 6-1 Relation Between Scour Depth and Discharge (Andru)



Legend

- Inglis; bridge pier and abutment
- Inglis; obstacle in channel
- Inglis; downstream of bridge
- Inglis; model test of hardinge bridge
- Laursen-Toch; model test of brdge pier and abutment
- Laursen; model test of bridge pier and abutment
- Ahmad; model test of groin
- Sanders smotrych; model test of groin and training dike
- Andru; groin and bridge pier

Fig. 6-2 Diagrams for Calculation of Scour Depth (Laursen)



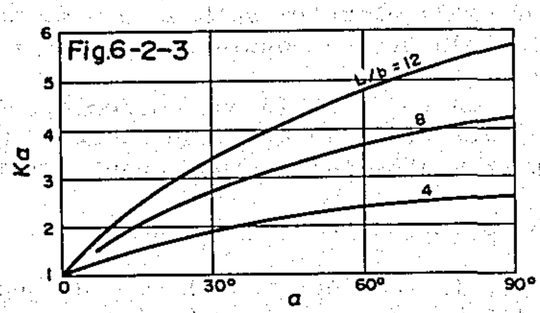
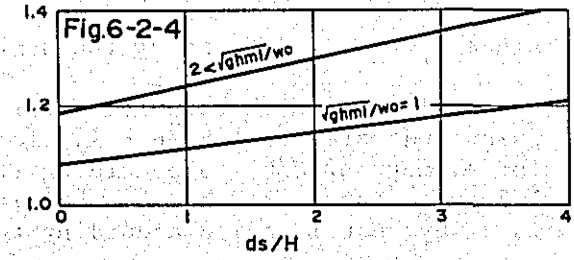


Fig.6-2-2

Nose form	Length-width ratio	Ks
Rectangular		1.00
Semicircular		0.90
Elliptic	2 : 1	0.80
	3 : 1	0.75
Lenticular	2 : 1	0.80
	3 : 1	0.70



$$d_s = 1.05\ b^{0.75} \quad (d_s,\ b : m) \qquad (6.4)$$

also for circular cylindrical piers.

Shen, Schneider and Karaki gave a formula

$$d_s = 0.000223\ R_e^{0.619} \quad (d_s : m) \qquad (6.5)$$

for the equilibrium scour depth in the clear-water scour region. R_e means the pier Reynolds number

$$R_e = Ub/\nu$$

where U is the mean velocity of the undisturbed flow and ν the kinematic viscosity.

The above-mentioned formulas from (6.1) to (6.5) are shown in Fig.6-3 in comparison. The values by Andru's, Laursen's and Shen and others' formulas are given with regard to the case of Sirajganj site in the preliminary study (Chapter V).

As seen in this figure, these formulas give a very wide range of values. It can be said, however, that (1) Andru's formula cannot hold with regard to piers of small diameter since scoured depth depends only on water depth according to the formula, (2) Laursen's formula may hold with regard to piers of large diameter because the formula was obtained for the range of H/b = 1 to 7, (3) Breuser's and Larras' formulas seem to be unreasonable in case of large diameter because these formulas are independent of water velocity and 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) Shen and others' formula seems to hold over a considerably wide range of pier width.

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

2. Scour Depth around Wide Piers.

If we adopt a well type as substructure, the width or the diameter will be of the order of 12 m. If we assume that b = 12 m, k_s = 0.90 and k_α = 1.0, Laursen's formula becomes

$$H_s = H + 0.9\ k_\tau d_s \qquad (6.6)$$

since $u_*/w_o > 2$ in case of the Jamuna River.

Values of H_s/H calculated for H/b = 1 to 7 are shown in Fig.6-4, which indicates that $H_s/H < 1.8$ for a range of $H/b > 3$ and $H_s/H > 1.8$ for a range of $H/b < 3$ according to Laursen's formula, while $H_s/H >$ 1.8 for a range of H/b 3 according to Laursen's formula, while H_s/H is always equal to 1.8 according to Andru's.

Fig. 6-3 Scoured Depth around Bridge Pier

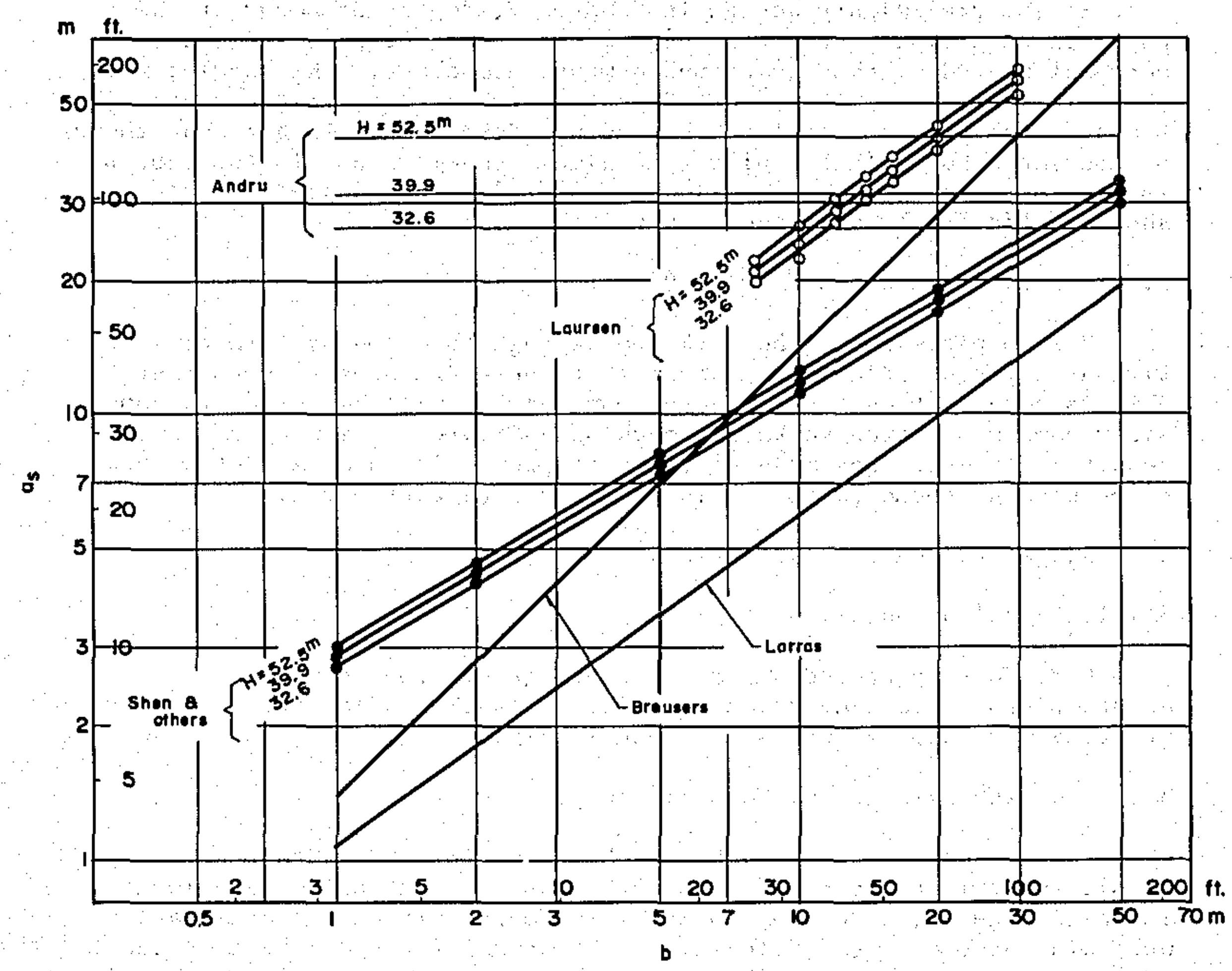
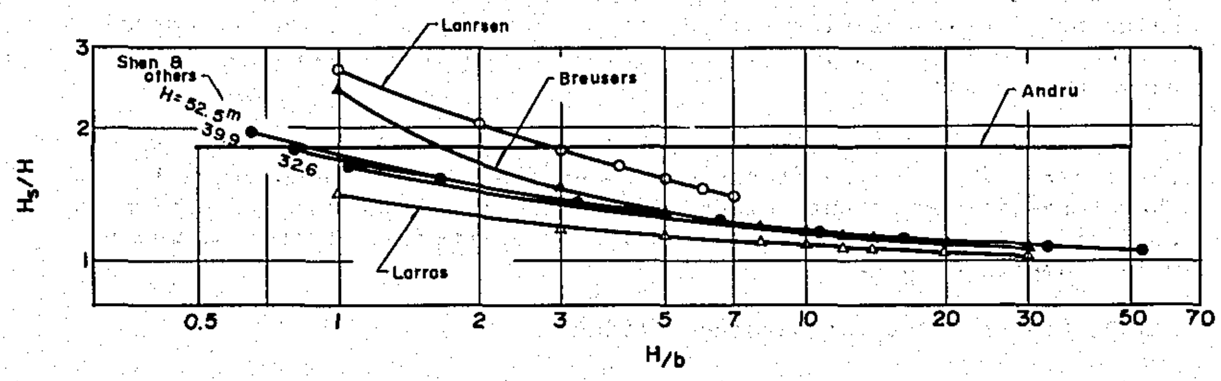


Fig. 6-4 Relation between H_s/H and H/b



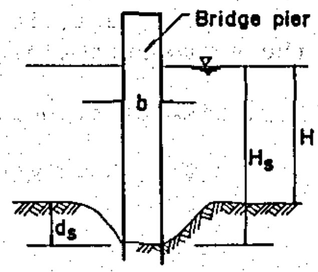
Notes ;

Andru ; $H_s/H = 1.8$

Breusers ; $d_s = 1.4b$

Larras ; $d_s = 1.05b^{0.75}$ (m)

Shen & others ; $d_s = 0.000223Re^{0.619}$ (m)



In the preliminary design in Chapter V, depths of scour at the piers in each type of the constructions at the four proposed sites were calculated by the two formulas mentioned above. The results are shown in Table 6-1. It is seen from this table that, in the types of A and B, the values calculated by Andru's formula are larger than those by Laursen's but both formulas give almost equal values in the type C. In view of these facts, the values by Andru's were adopted and are shown in Fig.5-6 by double-circle points.

3. Protection Works around Wide Piers.

Bridge piers should be sunk 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 will be forced to consider some protection works although undesirable. Thinking of this condition. a study was made of range of protection and size of stones to be placed around piers. This may be called pier apron.

3.1. Range of area for protection.

3.1.1. Gales' proposal.

R.R. Gales proposed a protection range of area to be taken around piers in consideration of oblique attack of flow and scattering of stones in falling, which is shown in Fig. 6-5.

3.1.2. K. Ishizaki and K. Honma's study.

Katsuyoshi Ishizaki and Katsuichi Honma (129 GB) obtained the result shown in Fig.6-6 and 6-7 on the basis of extensive experiments. In these figures, H denotes normal water depth without scour, q and v unit discharge and mean velocity in the normal water depth, X distance from the pier wall, r radius of the pier, d_s depth of scour at the pier wall or at X = 0, H' the scoured depth measured from the water surface, q' and v' unit discharge and mean velocity at the pier wall, and y a value of q'/q at the pier wall or at X = 0. Fig.6-6 shows the correlation between q'/q and X/r, and Fig.6-7 shows the correlation between d_s/H and y.

As seen in Fig.6-6, the ratio q'/q is larger than unity in the range X/r   2 or in the distance smaller than D from the pier wall. Therefore, it may be sufficient, if we take the range for protection as 2D from the pier wall in consideration of scattering of stones, where D is diameter of pier.

3.1.3. Present state at Hardinge Bridge.

According to the results of pricking around the piers of Hardinge Bridge, it is reported that stones have been scattered around the piers approximately within the range of about 2D from the pier wall.

3.2. Size of stones.

S.V. Isbash studies the stability of rock-fill dam in running

Table 6-1 Scour Depth around Bridge Pier

$b = 12.0^m$

Site	Type	Depth	Laursen's method			Andru's formula		Design water depth at piers
		H (m)	H/b	Hs/H	Hs(m)	Hs/H	Hs(m)	ft
Nagarbari	A	56.139	4.678	1.56	87.577	1.80	101.050	102^m (334.4)
	B	42.384	3.532	1.69	71.629	"	76.291	77 (252.5)
	C	36.825	3.069	1.77	65.180	"	66.285	67 (219.7)
Sirajganj	A	53.862	4.489	1.57	84.563	"	96.952	97 (318.0)
	B	40.749	3.396	1.71	69.681	"	73.348	74 (242.6)
	C	33.473	2.789	1.82	60.921	"	60.251	61 (200.0)
Gabargaon	A	54.891	4.574	1.56	85.630	"	98.804	99 (324.6)
	B	41.041	3.420	1.70	69.770	"	73.874	74 (242.6)
	C	35.554	2.963	1.80	63.997	"	63.997	64 (209.8)
Bahadurabad	A	50.542	4.212	1.60	80.867	"	90.976	91 (298.4)
	B	37.682	3.140	1.75	65.944	"	67.828	68 (223.0)
	C	31.229	2.602	1.86	58.086	"	56.212	57 (186.9)

Fig. 6-5   Pier Apron

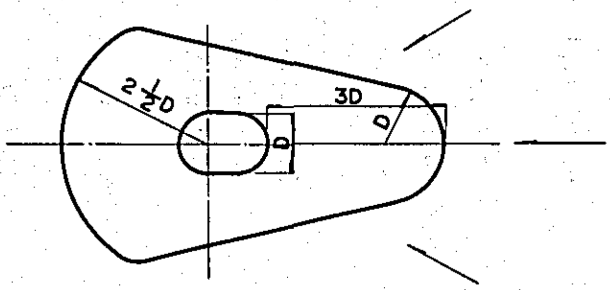


Fig. 6-6   Relation Between q'/q and x/r

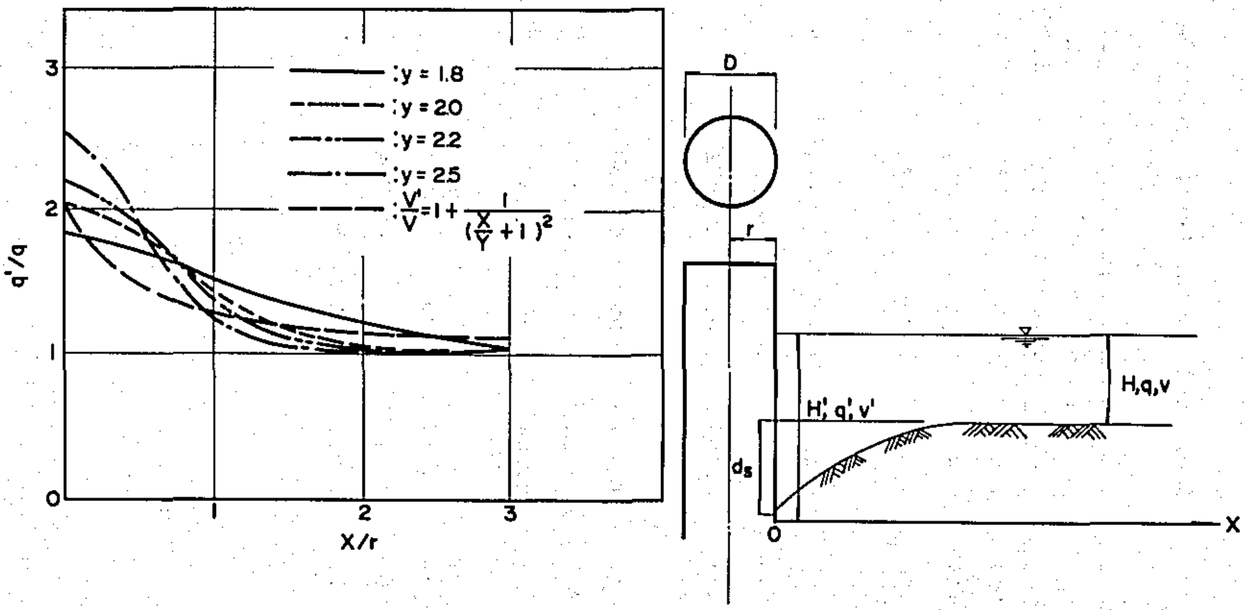
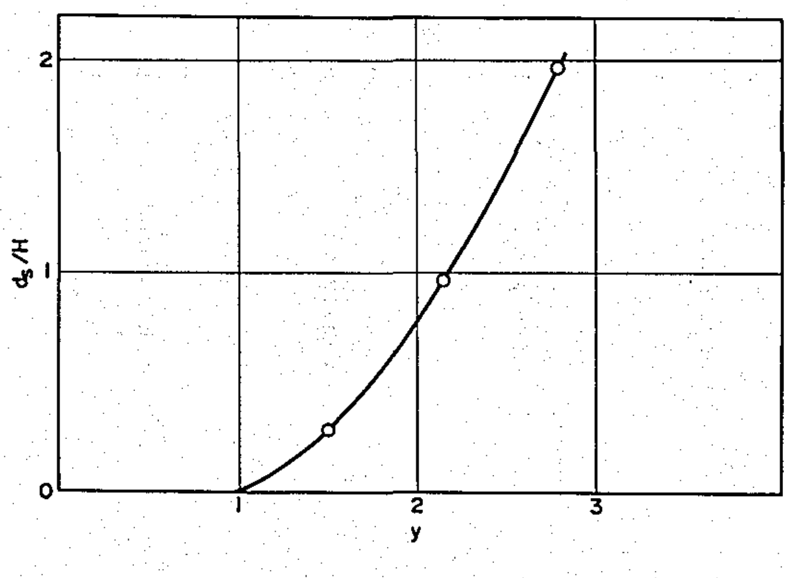


Fig. 6-7   Relation Between d_s/H and y



water and obtained the following formula giving the relation between flow velocity and weight of stones required for stability.

$$v = EK\sqrt{d}$$

$$K = \sqrt{2g(w_s - w_o)/w_o} \qquad (6.7)$$

where v = critical mean velocity (mean velocity on a vertical) (m/s)

d = diameter of a stone (m)
w_s = unit weight of stone (t/cub. m)
w_o = unit weight of water (t/cub. m)
g = acceleration of gravity (m/sq. s)
E = coefficient depending on shape of the crest of dam (nondimension).

The values of coefficient E are

$E = 0.86$ for triangular crest
$E = 1.20$ for trapezoidal crest.

In a local scour as shown in Fig.6-6,

$$v = q/H, \quad v' = q'/H'$$

$$\therefore \quad v' = (H/H')\gamma v \qquad (6.8)$$

Substituting the equation (6.8) into the equation (6.7), we get

$$d = (H/H')^2(\gamma/EK)^2 v^2. \qquad (6.9)$$

Therefore, we can estimate the size of a stone which will not be moved by the flow in the scour hole, if we can get the values of scoured depth, unit discharge at the pier wall and the mean velocity at the normal depth. Weight of the stone can be approximately estimated by the following equation.

$$W = 2.65(4/3)\pi(d/2)^3 \qquad (6.10)$$

Regarding the mean velocity v, we must take the velocity at the thalweg. Now, let v be the mean velocity at the thalweg and v_M the mean velocity of the whole water area, we get

$$v = (1/n)H^{2/3}I^{1/2}, \quad v_M = (1/n_M)R^{2/3}I_M^{1/2}$$

where n is coefficient of roughness, H water depth and I water-surface slope at the thalweg and n_M is coefficient of roughness, R mean depth and I_M water surface slope of the whole cross-sectional area. If we can approximately put

$$n = n_M, \qquad I = I_M$$

the mean velocity at the thalweg between both the guide banks can be estimated by the following equation

$$v = (H/R)^{2/3} v_M \qquad (6.11)$$

Now, if we take the values, $g = 9.8\ m/s^2$, $w_s = 2.65\ t/m^3$. $w_o = 1\ t/m^3$, and $E = 1.20$, the equation (6.9) becomes

$$d = 0.0215(H/H')^2 y^2 v^2. \qquad (6.12)$$

According to the study made by Ishizaki and Honma, the relation between d_s/H and y is given by Fig.6-7. If we take $H'/H = 1.8$ or $d/H = 0.8$, we get $y = 2.05$ from Fig.6-7. On the other hand, the theoretical solution gives

$$v'/v = 1 + (X/r + 1)^{-2}$$

for the stage of non-scour, or $y = 2$ at the pier wall. Therefore, we can understand that the value of y varies from 2 to 2.05 depending on the state of scour, from the beginning to the equilibrium, on the assumption that $H'/H = 1.8$ or $d_s/H = 0.8$.

Since the value of y at the equilibrium state of scour scarcely differ from that at the beginning of scour, we can use the value $y = 2.05$ for the intermediate state of scour. In this case, the equation (6.12) becomes

$$d = 0.09035(H/H')^2 v^2. \qquad (6.13)$$

Tables 6-2-1 to 6-2-2 give the values of diameter d and weight W of the stones which will resist to the flow expected to occur at the bottom of scour hole. For this calculation, the equations (6.13) and (6.10) were used and, as mentioned above, H means water depth at a thalweg, H_s the water depth from the water surface to the bottom of the scour in the equilibrium state and H' a water depth of the scour in a state on the way to the equilibrium.

It will be considered on the basis of the results of the calculation shown in Table 6-2-1 to 6-2-2 as follows.

(a) Theoretically, it is necessary to place stones larger than those shown below so as not to allow any scour around piers. In practice, stones smaller than these may serve if additional supply for maintenance is considered.

Type A;	Nagarbari site	d = 135 cm	w = 3,430 kg
	Sirajganj site	d = 171 cm	w = 6,960 kg
	Gabargaon site	d = 166 cm	w = 6,370 kg
	Bahadurabad site	d = 196 cm	w =10,480 kg
Type B;	Nagarbari site	d = 115 cm	w = 2,120 kg
	Sirajganj site	d = 146 cm	w = 4,340 kg
	Gabargaon site	d = 144 cm	w = 4,160 kg
	Bahadurabad site	d = 171 cm	w = 6,960 kg
Type C:	Nagarbari site	d = 100 cm	w = 1,380 kg
	Sirajganj site	d = 122 cm	w = 2,520 kg
	Gabargaon site	d = 125 cm	w = 2,740 kg
	Bahadurabad site	d = 140 cm	w = 3,820 kg

Table 6-2-1 Weight of Pitching Stone for Pier Apron

Site: Nagarbari

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

Site: Sirajganj

Type	B (m)	vm (m/s)	H (m)	v (m/s)	H' (m)	H/H'	d (m)	W (t)
					Hs = 96.952 Hs/H = 1.8			
					53.862	1	1.712	6.959
					60	0.898	1.381	3.653
A	2,000	2.246	53.862	4.356	70	0.769	1.013	1.442
					80	0.673	0.776	0.648
					96.952	0.556	0.529	0.205
					Hs = 73.348 Hs/H = 1.8			
					40.749	1	1.463	4.343
					50	0.815	0.971	1.270
B	4,200	1.780	40.749	4.026	60	0.679	0.674	0.425
					70	0.582	0.495	0.168
					73.348	0.556	0.452	0.128
					Hs = 60.251 Hs/H = 1.8			
					33.473	1	1.220	2.518
					40	0.837	0.854	0.864
C	5,600	1.625	33.473	3.676	50	0.669	0.546	0.226
					60	0.558	0.380	0.076
					60.251	0.556	0.377	0.074

Table 6-2-2 Weight Pitching Stone for Pier Apron

Site: Gabargaon

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

Site: Bahadurabad

Type	B (m)	vm (m/s)	H (m)	v (m/s)	H' (m)	H/H'	d (m)	w (t)
					Hs = 90.976		Hs/H = 1.8	
					50.542	1	1.961	10.479
					60	0.842	1.391	3.807
A	2,000	2.400	50.542	4.662	70	0.722	1.022	1.481
					80	0.632	0.783	0.669
					90.976	0.556	0.606	0.309
					Hs = 67.828		Hs/H = 1.8	
					36.682	1	1.711	6.962
					45	0.837	1.199	2.400
B	4,200	1.925	37.682	4.354	52	0.725	0.899	1.011
					60	0.628	0.675	0.429
					67.828	0.556	0.529	0.207
					Hs = 56.212		Hs/H = 1.8	
					31.229	1	1.401	3.824
					37	0.844	0.998	1.379
C	5,600	1.742	31.229	3.940	43	0.726	0.738	0.558
					50	0.625	0.547	0.228
					56.212	0.556	0.433	0.113

(b) If a pier be sunk 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.

(c) If we want to reduce secured depth or hold a depth H' smaller than H_s, 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 maintenance supplement of stones.

(d) 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.

3.3. Thickness of stones to be placed.

In our judgement, it will be necessary to provide the same thickness as in the case of the apron in the meaning of preventing the leakage of sand through voids of the placed stones.

CHAPTER VII

COMPARISON OF THE FOUR PROPOSED SITES

1. Geomorphological Comparison.

M. Ohya prepared geomorphological land classification maps of the four areas including the proposed bridge sites by photointerpretation and field investigations. These are shown in Figs.7-1 and 7-2.

1.1. Bahadurabad site and its vicinity.

There are alluvial fans along both banks of the river. The alluvial fans in Japan consist of sand and gravel and have steep slopes, but it is merely sand and very flat in the Bahadurabad region. This phenomena are caused by severer chemical-weathering of rock than in Japan because this area belongs to a subtropical region. Also the width of the fan is narrow but the length is short. Two alluvial fans are developed as long narrow stripes along the left bank. Old alluvial plains which consist of natural levees and back-swamps are located in the above-mentioned fans. The old alluvial fans were formed before 1830. The shape of the fan indicates that the formation process is not completed yet.

1.2. Gabargaon site and its vicinity.

Width of the alluvial fan in this area is wider than that in the Bahadurabad region. Old alluvial plains formed before 1830 are seen here and there in the fan. The old alluvial plains consist of natural levees, back-swamps, former river courses, etc. On the right bank, there are a number of large river courses.

1.3. Sirajganj site and its vicinity.

The above-mentioned two places are alluvial fans but the Sirajganj area is a natural levee region. Several distributaries are diverted at Bahadurabad but astricted at the upper part of the Sirajganj area. Namely the distributaries form anabranches. Thereafter the distributaries are diverted again at the lower reaches of the Sirajganj area. There are cliffs about 4 m high between the present alluvial plain and the old alluvial plain on the left bank of the Jamuna River. Distinct regional differences in topography are seen between the present alluvial plain and the old alluvial plain as shown in Fig.7-2. There are many natural levees in the old alluvial plain but few in the present alluvial plain. The town of Sirajganj is located in the old alluvial plain, that is, the town is located in a narrow of the plain (about 10 km or 6.2 mi in width) which was formed by the old alluvial plain. The villages located on the natural levees on the right bank were founded 150 or 200 years ago.

1.4. Aricha, Nagarbari and their Vicinity.

There are distinct differences in regional geomorphology between the left and the right banks in this region. There is a big swamp-area

Fig.7-1 Geomorphological Land Classification Map of the Jamuna River Basin

Bahadura bad, Gobargaon and It's Surrounding Area

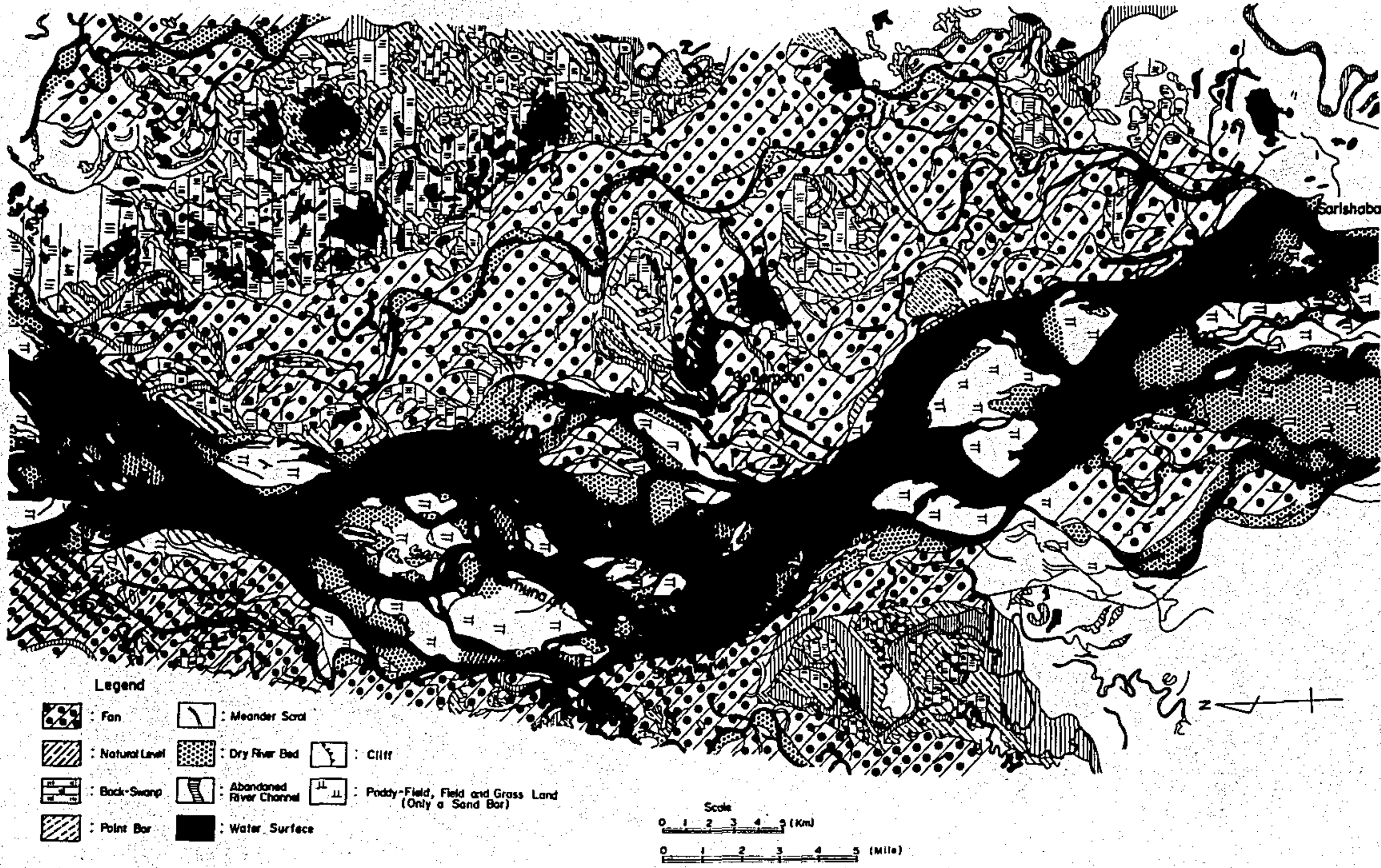
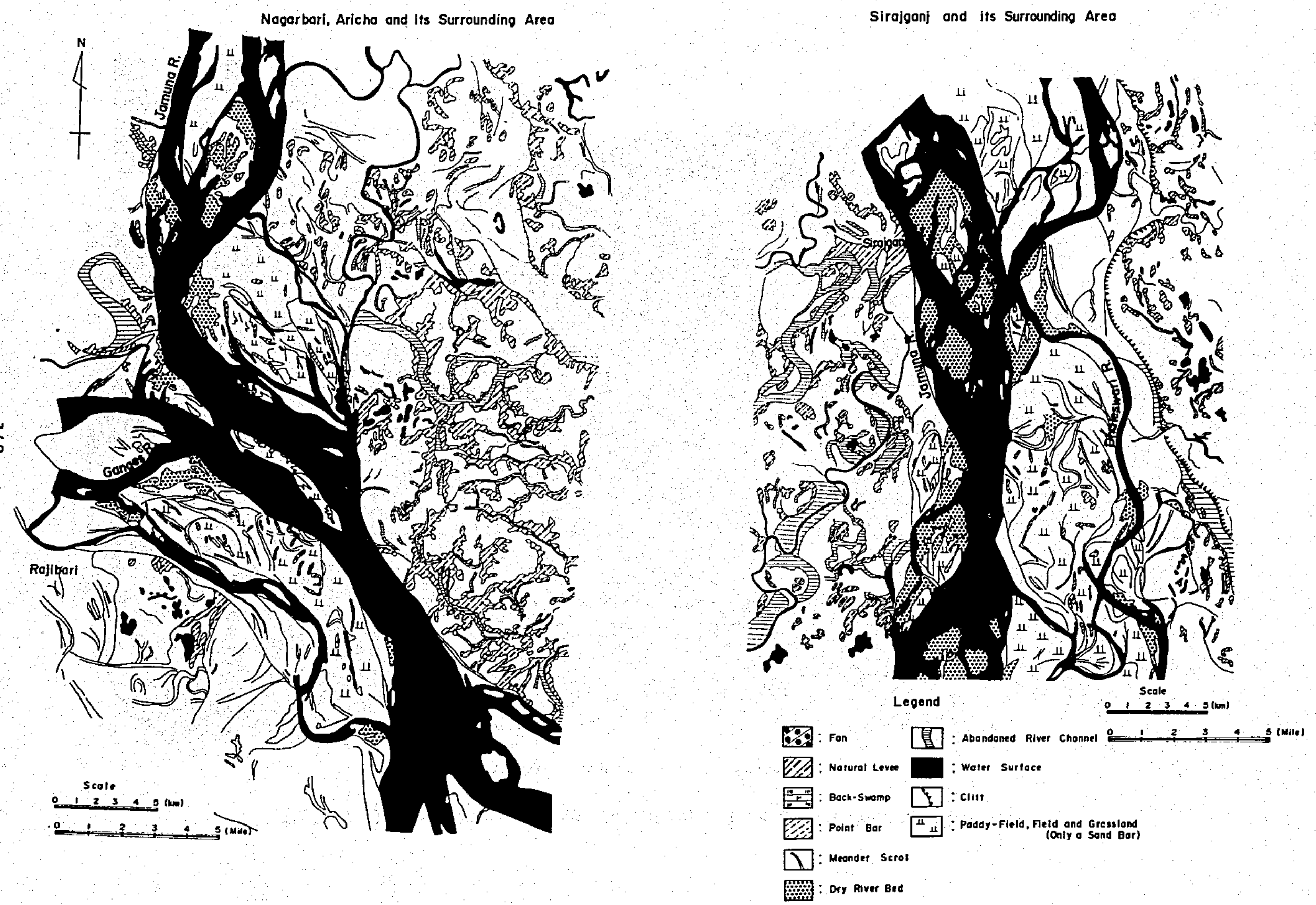


Fig.7- 2 Geomorphological Land Classification Map of the Jamuna River Basin



on the right bank. The area was formed by the back-water of the Ganges during flood time. On the left bank, natural levees are developed. The levees were formed not by the present Jamuna River but the former rivers. There is a distinct former river course whose width is about 3.5 km or 2.2 mi on the left bank.

1.5. Comparison of the four sites.

The geomorphological features of the four sites are summarized in Table 7-1. Namely the Bahadurabad and Gabargaon sites are located on the alluvial fan, whereas Sirajganj is located in a natural levee regior and Nagarbari and Aricha are located in natural-levee or delta regions.

Generally speaking, shifting of river courses in the alluvial fan was frequent. The width of the river in the alluvial fan is wider than that in the natural levee region because it is difficult to confine flood water within banks in the former cases. Furthermore, age of formation of the alluvial fan is new, namely since 1830. Therefore, it is still unstable in the Bahadurabad and Gabargaon regions. But we can find that the stage of the Jamuna River in these regions is advancing little by little. There are small and narrow natural levees being formed along the river courses. This shows that the river courses are being stabilized little by little.

River course in natural-levee region is more stable than that in alluvial fan. The reason is as follows; natural levee has not been formed by flood flow from upper reaches but by overflow from the main channel to its adjacent regions. Natural levees formed in stripes indicate stability of the river course. In Japan, there are more bridges in natural levee region than in alluvial fan. From this viewpoint, we can regard that the Sirajganj site is the most stable place among the four.

Aricha and Nagarbari are located in the natural levee or the delta region. But the region is remarkably influenced by the flow of the Ganges. It was found that changes in river banks in this region are the largest among the four.

At Sirajganj, there is a narrow which has been formed by the old alluvial plain, whose width is about 10 km or 6.2 mi. According to studies of plains in Japan, a narrow is located in an anticline region but a wider area is located in a syncline region. If further research can be conducted in this region, we will be able to confirm the process of formation of this narrow.

2. River-morphological Comparison.

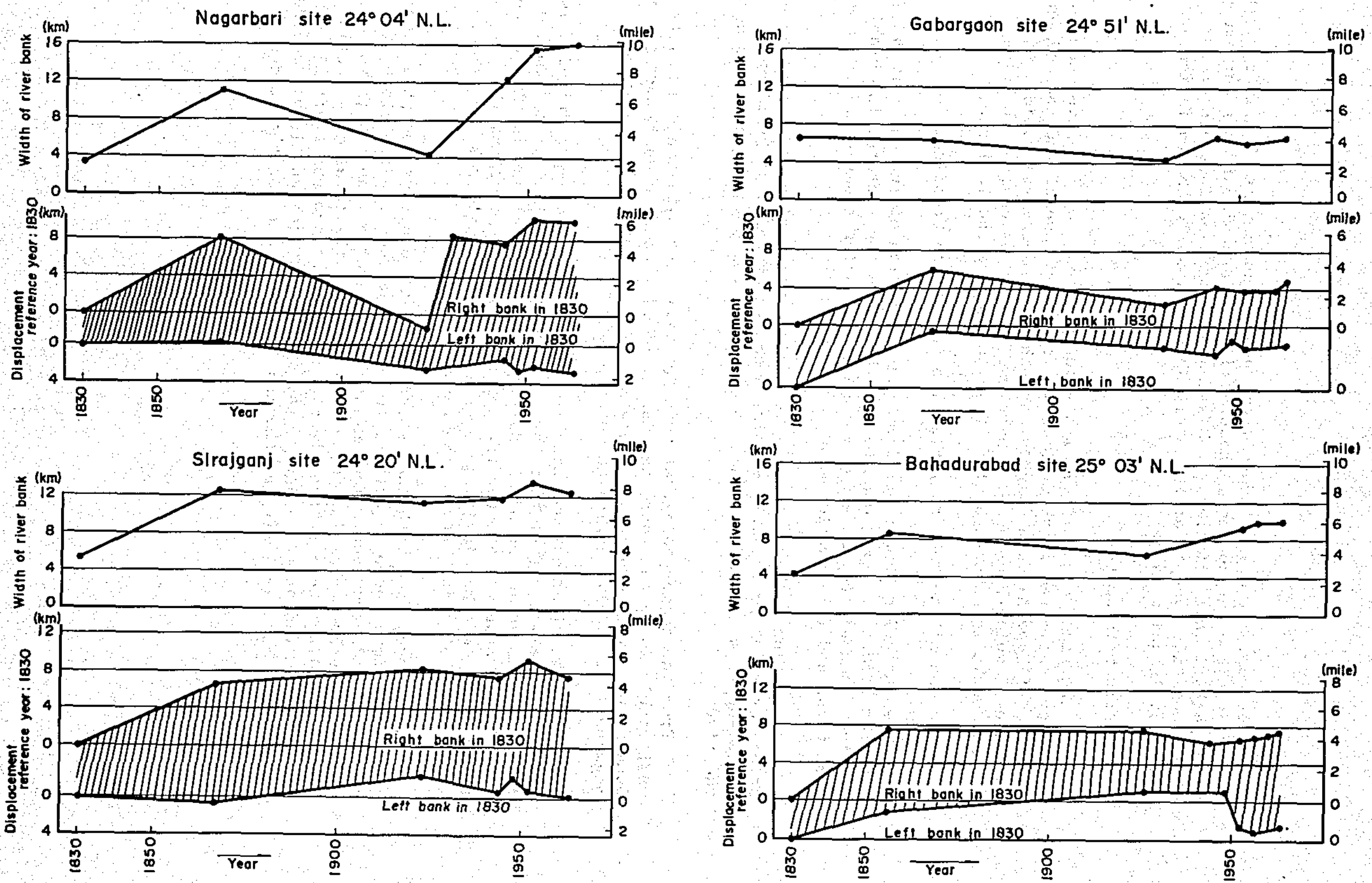
Changes in bank lines of the Jamuna River were studied in 3, Chapter II and they were shown in Fig.2-7 and Fig.2-8. It is seen from these figures that the propossd bridge sites are rightly situated at nodes of width variation along the river course and the variation of the banklines is comparatively stable at these nodes.

Fig. 7-3 shows time variation of river width and time variation of banklines at the proposed bridge sites taking the year of 1830 as

Table 7-1 Comparison of geomorphology among the four proposed bridge sites

Item of Comparison / Place Name	River morphology	Geomorphology of inland region			
		Left bank		Right bank	
		Geomorphological element		Geomorphological element	
		Deposition by Jamuna River	Deposition by former river	Deposition by *Jamuna River*	Deposition by *former river*
BAHADURABAD	Braided stream Alluvial fan	Alluvial fan Natural levee Back-swamp Point bar Former river course (big)	Natural levee Back-swamp Point bar	Alluvial fan Natural levee	Natural levee Back-swamp
GABARGAON	Braided stream Alluvial fan	Alluvial fan Natural levee Former river course (big)	Natural levee Back-swamp	Alluvial fan Natural levee Back-swamp	Natural levee Back-swamp
SIRAJGANJ	Natural levee	Natural levee Back-swamp	Natural levee (big) Back swamp	Natural levee Back-swamp	Natural levee (big) Former river course (clear)
NAGARBARI	Natural levee Change of the river bank is remarkable	Natural levee Back-swamp Delta	Natural levee Back-swamp Delta	Natural levee Back-swamp Delta	Natural levee Back-swamp Delta

Fig. 7-3 Displacement of River Banks



the reference. It may be found from these figures that the river widths at Sirajganj, Gabargaon and Bahadurabad sites are almost constant except for Nagarbari and variations of displacement of banklines are also almost constant except for the early 30 years, while the variation at Nagarbari is quite large.

3. Comparison in Costs.

At the stage of the preliminary design, costs of the river control works were estimated in 8, Chapter V. In every case of the four sites, the cost of Type-A is the highest and the cost decreases rapidly with increase of guide-bank span. Therefore, so far as cost of the river control works is concerned, Type-C is the most economical one.

4. Selection of the Most Suitable Site for Bridge Crossing.

The Inception Report mentions that selection of the most suitable site for bridge crossing must be made based on the factors; (a) stability of river channel, (b) construction costs including those of river control works and (c) traffic voluem.

As mentioned above, all the four sites which have been proposed as bridge crossing points are certainly located at nodes of braiding, which suggests that any of them is favorable for spanning a bridge across the river.

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.

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 banklines 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 geomorphological and river-morphological points of view, there is nothing to choose between the two sites of Sirajganj and Gabargaon. Taking into consideration the other two factors together, that is, further considering the total construction costs including those of the river control works and the traffic volume estimated at the stage of the preliminary design, it was decided to take the Sirajganj site as the most suitable one for the bridge crossing.

Phase II Second stage of the study

CHAPTER VIII

RIVER CONTROL WORKS AT SIRAJGANJ SITE

1. Determination of Spanning Site.

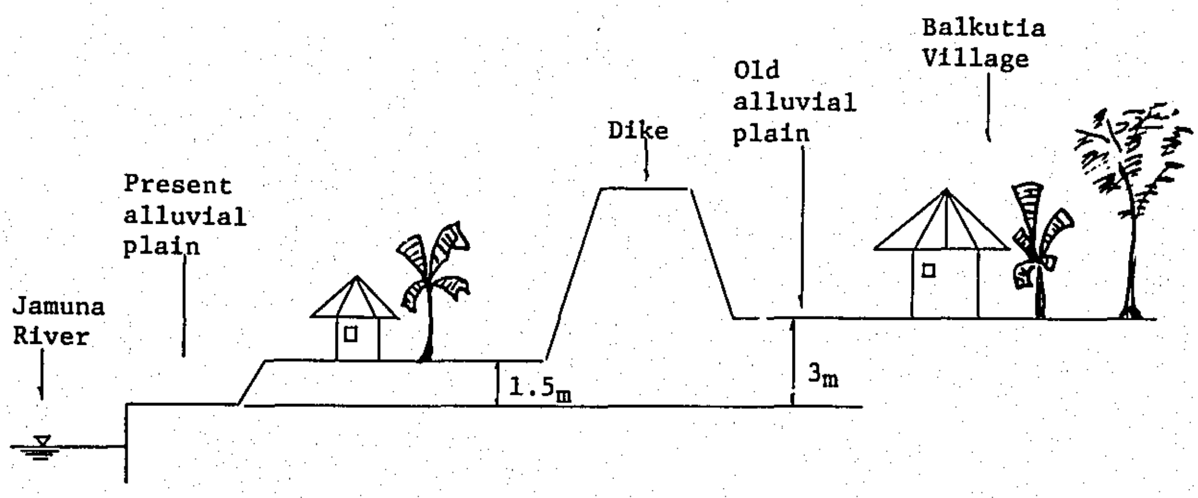
At a meeting which was held at Dacca from Oct. 28, 1974 to Nov. 6, 1974, Sirajganj site was chosen as the most suitable site and the spanning site or the bridge axis was located during the Study Teams' stay in Dacca from Nov. 29, 1974 to Dec. 14, 1974 based on the aero-photographs newly taken by the Japanese Surveying Team in Nov. 1974.

Topography of the area surrounding the bridge axis is shown in Fig.8-1.

M. Ohya prepared a geomorphological land classification map of the Sirajganj area utilizing the above-mentioned photographs. This is shown in Fig.8-2.

Two alluvial terraces are found on the left bank in the Sirajganj site. As shown in Fig.8-3, relative height of the lower terrace is 1.5 m and that of the higher terrace is 3 m. The lower terrace is utilized as upland-crops field. This area is not inundated by ordi-

Fig.8-3 Schematic Cross Section of the Left Bank of the Sirajganj Area



nary floods but occasionally inundated when high floods occur. The depth of inundation is relatively shallow. Small villages have been settled for 25 or 30 years on this lower terrace.

The higher terrace is surrounded by cliffs as shown in Fig.8-3. The cliff continues from north to south but the relative height is highest on the opposite side of Sirajganj Town. Balkutia Village which is located on this terrace is surrounded by dikes which were con-

Fig. 8-1 Topography of the Area Surrounding the Axis

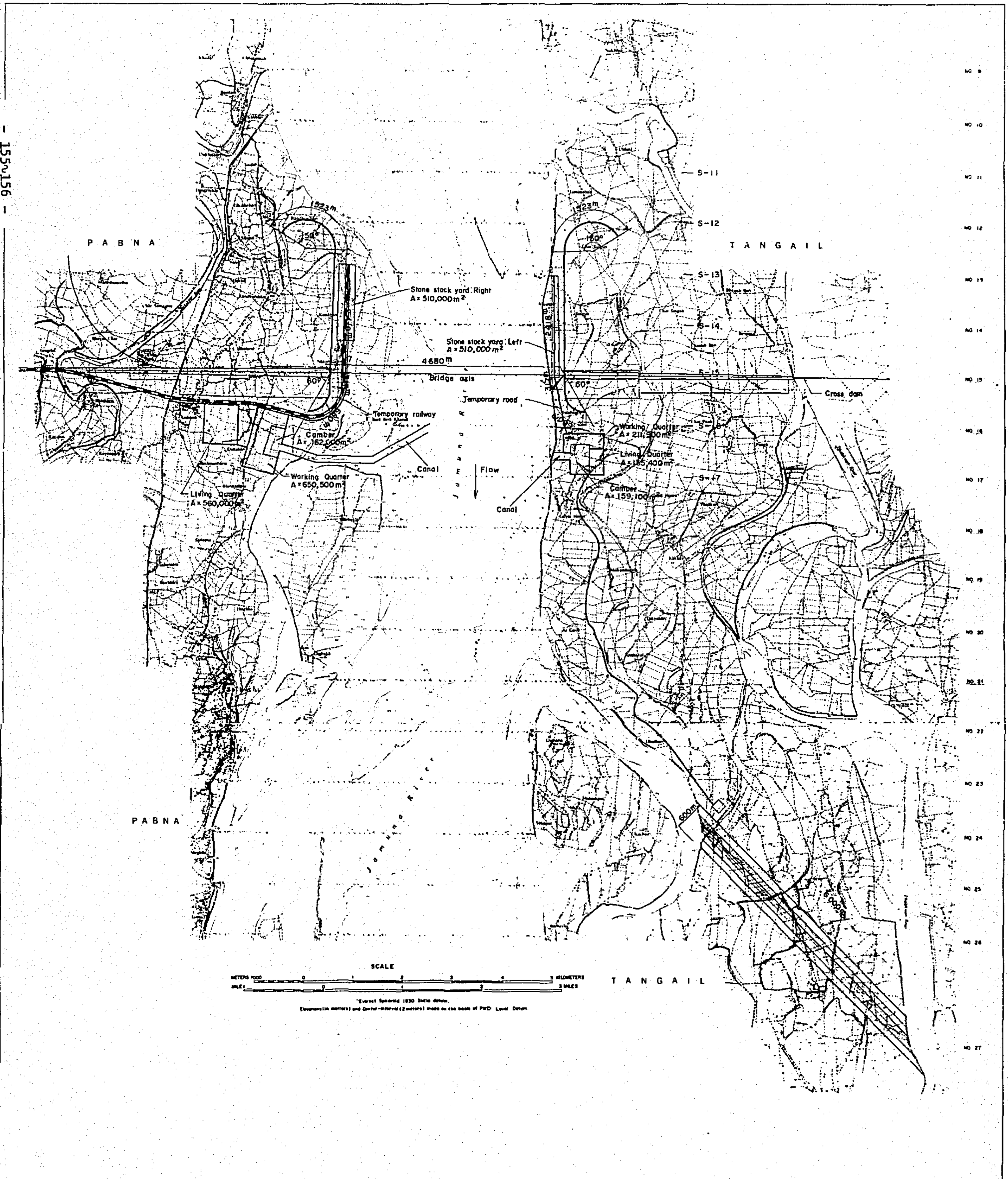


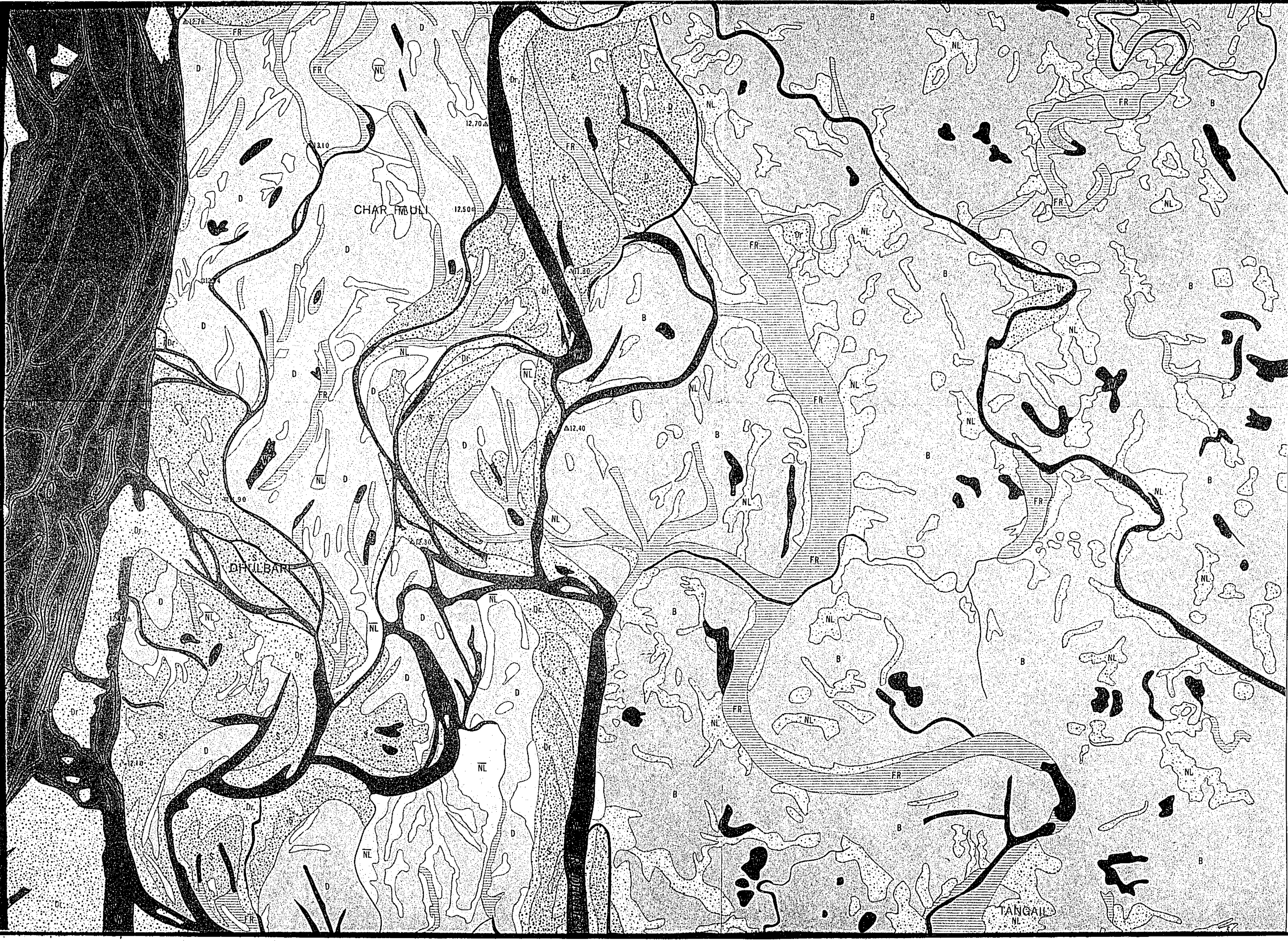
Fig. 8-2 GEOMORPHOLOGIC MAP OF THE BRAHMAPU
(SIRAJGANJ AND ITS SURROU

C MAP OF THE BRAHMAPUTRA-JAMUNA RIVER BASIN
AJGANJ AND ITS SURROUNDING AREA)


R. HURASAGAR
AMBARIA
CHAR HAULI

Dr
S
D
NL
FR
B
12.76
12.70
12.50


AMBARIA
SAHAGPUR
DHULBARI


CHAR
DHULBARI
TANGAIL
D
Dr
S
FR
NL
B

EXPLANATORY NOTES

	BOUNDARY OF TOPOGRAPHY AND CLIFF
NL	UPPER NATURAL LEVEE
$\overline{NL}$	NATURAL LEVEE FORMED BY R. BRAHMAPUTRA-JAMUNA DURING THE LAST 140 – 160 YEARS
B	BACK – SWAMP
FR	FORMER RIVER COURSE
$\underline{D}$	UPPER SANDY DELTA
D	SANDY DELTA FORMED BY R. BRAHMAPUTRA-JAMUNA DURING THE LAST 140 – 160 YEARS
S	SAND BANK COVERED BY VEGETATION
Dr	DRY RIVER BED
	WATER SURFACE
	CONTOUR LINE OF THE GROUND HEIGHT IN METERS OF THE RIVER BED

BASE PHOTO MAP WAS MADE FROM AERIAL PHOTOGRAPHS TAKEN IN DECEMBER 1974.

ELEVATIONS AND CONTOUR LINES WERE TRACED AND COMPILED FROM THE BASE MAP WHICH WAS MADE BY THE JICA AND THE GOVERNMENT OF BANGLADESH (ELEVATIONS IN METERS AND CONTOURS MADE ON THE BASIS OF PWD LEVEL DATUM)

PUTRA-JAMUNA

WATER SURFACE

CONTOUR LINE OF THE GROUND HEIGHT IN METERS OF THE RIVER BED

SCALE 1:50,000

SURVEYED, COMPILED AND CARTOGRAPHED
BY MASAHIKO OHYA

PRINTED BY KOKUDO CHIZU CO., LTD. TOKYO 1976

structed in 1965. Before construction of the dikes, this area was sometimes inundated during high floods but after the construction of dikes, no inundation has occured. There are not only upland-crop fields, but also many big trees. From the research by hearing and the size of these big trees, it was found that the village was founded 150 or 200 years ago, that is, around the same year or just before the present Brahmaputra-Jamuna River was formed. Sirajganj is also an old town.

As seen in Fig.8-3, there are geomorphological regional differences between the inside of the cliff i.e. protected area and the outside of it i.e. unprotected area. The former has many but small natural levees but the latter was few. M. Ohya presumed that the natural levees were formed not by the present Brahmaputra-Jamuna River but by the rivers such as the Tista which flowed in the area before formation of the present Brahmaputra-Jamuna River.

Based on the photo-interpretation of the ERTS, M. Ohya found a light black-colored belt crossing the Brahmaputra-Jamuna River from NNW to SSE at Sirajganj. The belt is presumed to be an old alluvial plain. This indicates that the old alluvial plain which had been formed not by the present Brahmaputra-Jamuna River but by the former rivers such as the Tista was developed around Sirajganj. At Sirajganj, there is a narrow (about 10 km in width) which consists of old alluvial plain which was formed 150 or 200 hears ago. This means that Sirajganj and its opposite side have been stable for the last 150 or 200 years. Except for Sirajganj and its opposite side we can not find any place of old alluvial plain. This is the main reason why this place is suitable for bridge construction from the viewpoint of geomorphology.

As mentioned previously in Chapter VII, the upper region from Sirajganj is an alluvial fan, whereas the lower region is a natural levee region. The river course in the natural levee region is more stable than that in the alluvial fan. Also from this viewpoint, the Sirajganj site is suitable for bridge crossing.

In view of topographical consideration of the aerophotograph and geomorphological consideration mentioned above, the bridge axis was chosen about 12 km downstream of the town of Sirajganj as shown in Fig.8-1. In accordance with the idea mentioned in Chapter III, guide-bank system was adopted together with cross dikes for the purpose of guiding flow and protecting bridge abutments and approaches. The arrangement of the guide banks and the cross dikes are shown in Fig. 8-1. In this case, the left-side approach must cross the Dhaleswari River. But, if the approach will cross the river by a bridge, this opening on the approach may have a posibility of inducing flood flow and causing serious damages to the approach and the bridge as well. In order to protect the approach from this menance, we will have to place another pair of guide banks around this opening. This pair of guide banks will be built nearly on the same scale as the main guide banks and especially, the right bank on the Dhaleswari will have to be connected with the left guide bank of the Jamuna.

This system ought to need another huge cost and, in spite of this treatment, will not be able to escape from the menace of strong flood flow to run through the opening. Therefore, we decided to cross the Dhaleswari by a cross dam and to connect the Dhaleswari with the Jamuna by excavating a new channel making use of a branch located about 6 km downstream of the bridge axis. This is also shown in Fig. 8-1.

Further in future, in making detail designs, hydraulic model tests are recommendable for determing the allignment and the length of the guide banks including the Dhaleswari new channel.

2. Design discharge.

The flood said to the biggest discharge in the record of Jamuna River arose in July 1974. According to B.W.D.B., water level and discharge recorded at Bahadurabad station are as follows.

Date	Aug. 7th, 1974
W.L.	65.55 ft PWD
Discharge	3,210,000 cfs (90,920 m^3/s)

This discharge, as easily recognized when compared with the discharges in Table 2-3, is extremely big.

This flood is not included in the samples for statistical analysis in 1, Chapter IV, becausd this happed after the study on Phase I. As this discharge is very important, the statistical analysis has been excuted again with the same procedure as in 1, Chapter IV, including this discharge and data in 1971 that were proved to be available afterwards, into the samples in Table 2-3.

Table 8-1 shows the data and Fig.8-4 shows the calculation result by Thomas plot method.

Table 8-2 shows the return period of discharge based on Fig.8-4. The series 1, 2, 3, 4 of these calculation are the same as mentioned in 1, Chapter IV.

Based upon this results, under the same reason as in 1, Chapter IV, the average value of the series 1, 2, 3, 4 has been taken as the return period of discharge at Bahadurabad site.

Design discharge is as shown in Fig.8-5 as the results of discharge allocation with the same idea as explained in 2, 3, Chapter IV.

Based on Fig.8-5, the design discharge for bridge construction at Sirajganj site has been determined as 96,850 m^3/s (3,420,000 cfs).

3. Guide-bank Span and Design High-water Level.

The design discharge was determined as 3,420,000 cfs or 96,850 cub. m/s as already mentioned above. Net minimum width between the pair of guide banks was calculated at 4,200 m for th is discharge by using the third method mentioned in Chapter III. On the other hand, the study in the bridge planning gives a span of 177.5 m as the most economical one and a pier width of 13 m as required therefore. Hence we need 26

Fig. 8-4 Return Period of Discharge at Bahadurabad

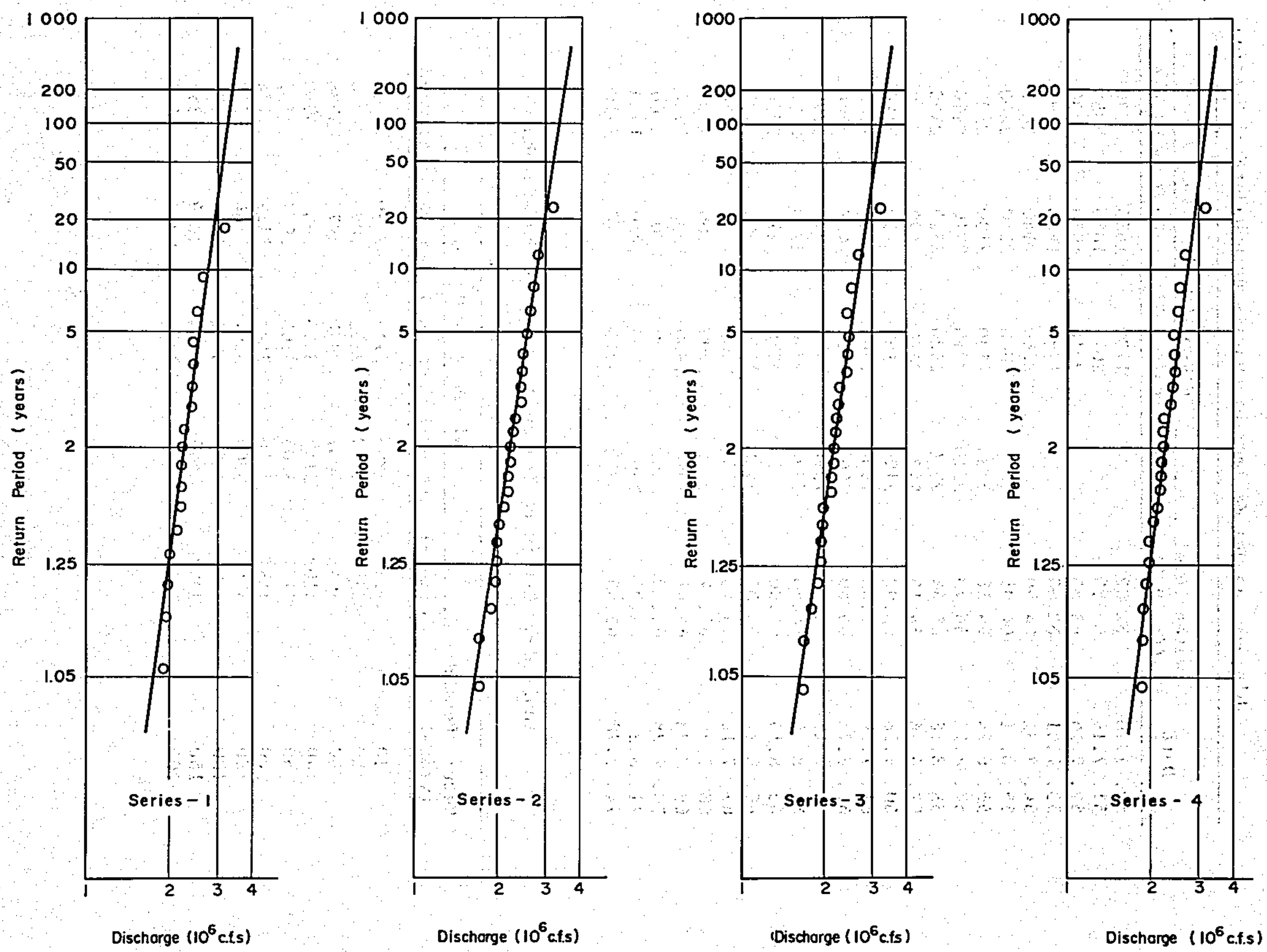


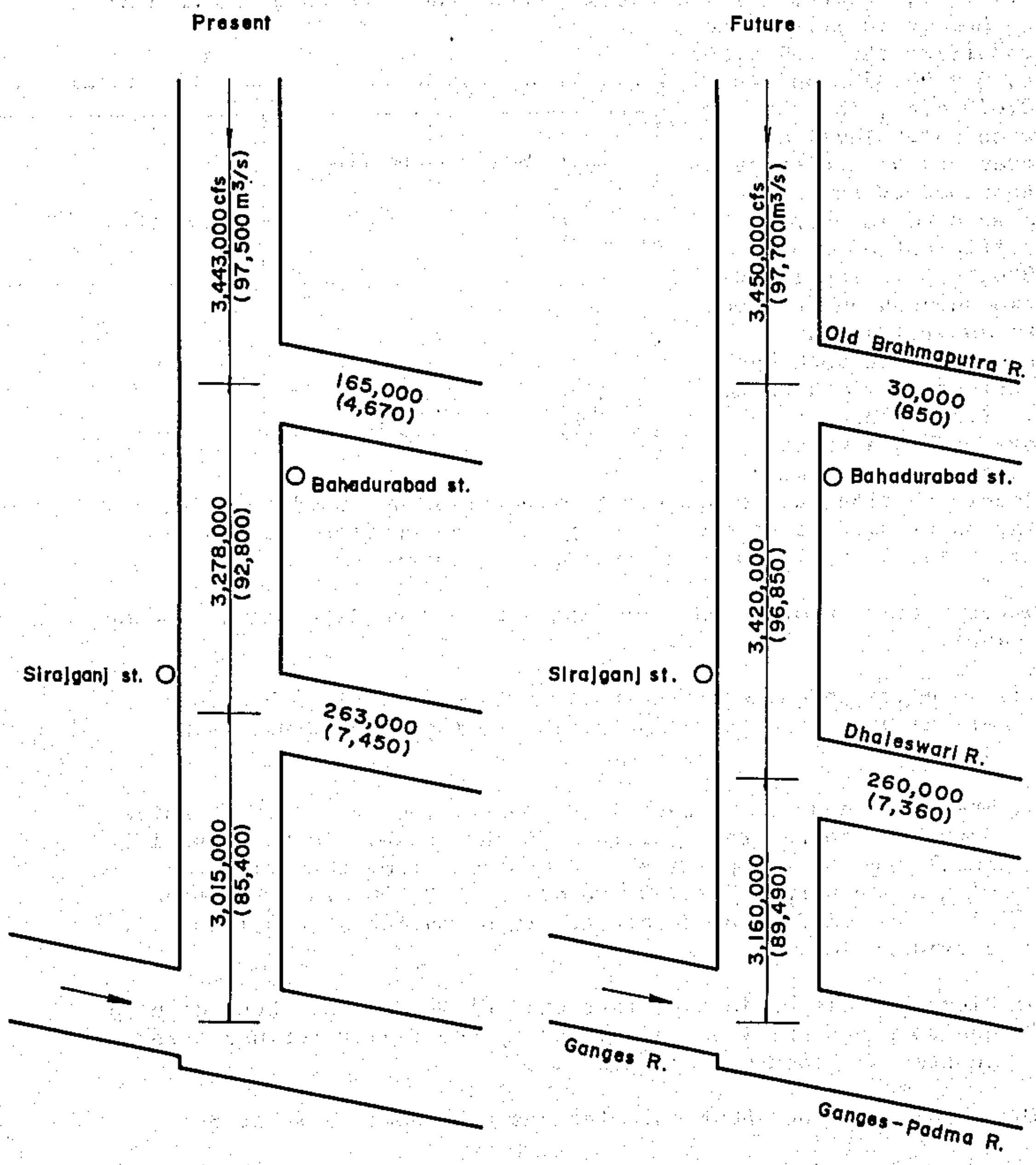
Table 8-1 Annual Maximum Discharges at Bahadurabad Station

Date	water level (ft, PWD)	Discharge (10^3 cfs)			
		series-1	series-2	series-3	series-4
50. 7.20	62.02		1730	1680	1870
51. 7.19	62.80		2020	1800	2050
52. 7.15	63.55		2310	1950	2230
53. 7.31	62.00		1730	1680	1890
54. 7.31	64.50		2660	2140	2450
55. 8. 1	64.95		2800	2240	2600
56. 6.24	64.18	2130	2130	2130	2130
57. 8.12	64.78	2210	2210	2210	2210
58. 8.18	65.65	2520	2520	2520	2520
59. 6.26	64.15	2420	2420	2420	2420
60. 9.18	63.90	2190	2190	2190	2190
61. 7.19	62.03	1900	1900	1900	1900
62. 8.23	65.60	2460	2460	2460	2460
63. 7.16	63.43	1990	1990	1990	1990
64. 8. 4	64.40	2230	2230	2230	2230
65. 8.15	64.00	2270	2270	2270	2270
66. 8.31	64.05	2430	2430	2430	2430
67. 7.12	63.43	2460	2460	2460	2460
68. 7.25	64.22	2200	2200	2200	2200
69. 7.23	64.65	1980	1980	1980	1980
70. 7.28	65.20	2700	2700	2700	2700
71. 8.21	63.05	1960	1960	1960	1960
74. 7.28	65.55	3210	3210	3210	3210

Table 8-2 Return Period of Discharge at Bahadurabad (by Thomas method)

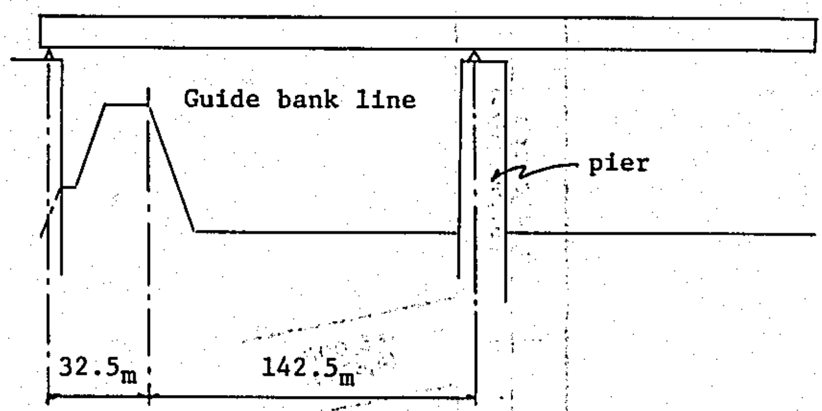
Return Period (years)	Discharge (10^3cfs)				
	Series-1	Series-2	Series-3	Series-4	Average
10	2797	2809	2719	2739	2766
20	2960	2989	2893	2893	2934
30	3048	3087	2990	2977	3026
40	3109	3154	3055	3-34	3088
50	3154	3205	3105	3077	3135
60	3191	3246	3145	3112	3174
80	3248	3309	3207	3166	3233
100	3291	3358	3254	3207	3278
150	3369	3444	3338	3279	3358
200	3422	3504	3396	3330	3413

Fig. 8-5 Discharge Allocation of Jamuna River
(for 100yr. flood')



piers in total. If we assume 25 % of the total widths of the piers to be a loss of width to be added to the total piers width and assume an arrangement of guide bank and abutment as shown below, we obtain 4,680 m or 15,354.3 ft as the guide-bank span.

Using the topographic map and the cross sections of the river which were prepared by the Japanese Surveying Team based on the surveyings which were made during the dry season from November 1974 to February 1975, water level was calculated on the stretch of 23 km from Section No. 26 to Section No. 3 on condition that (a) discharge; Q = 96,850 cub.m/s (3,420,000 cfs), (b) the reference water level at the lower end of the stretch is determined by the same method as used in Chapter V, (c) coefficient of roughness is 0.020, (d) interval between two successive sections is 1 km and (e) distance between cliffs on both banks is an effective width of the river. Since there are shallows within a width, river section was treated as a double section and nonuniform-flow equation was used for the calculation assuming that the discharge will be confined within two embankments to be built on both banks in the future.



Water surface profile was calculated with regard to the following three cases.

Case 1: There are no guide banks and the Dhaleswari River branches at the present bifurcation; that is, the present natural state.

Case 2: The river channel in Case 1 is constricted by a pair of guide banks but there are no piers. In this case, the Dhaleswari shall branch at a point 6 km downstream from the bridge axis with a discharge of 7,360 cub.m/s or 260,000 cfs. Lowering of river bed due to the constriction shall be taken into consideration.

Case 3: Piers are placed in the river channel in Case 2. Loss of head due to piers shall be calculated by the Nagler formula using constants obtained by Yarnel.

The results of the above calculations are shown in Table 8-3.

Table 8-3. Water Level on the Stretch of 23 km of the Sirajganj Bridge Site

NO	Case 1		Case 2		Case 3	
	P.W.D.(m)	P.W.D.(ft)	P.W.D.(m)	P.W.D.(ft)	P.W.D.(m)	P.W.D.(ft)
26	14.550	47.74	14.550	47.74	14.550	47.74
25	14.611	47.94	14.611	47.94	14.611	47.94
24	14.654	48.08	14.654	48.08	14.654	48.08
23	14.685	48.18	14.685	48.18	14.685	48.18
22	14.710	48.26	14.710	48.26	14.710	48.26
21	14.747	48.38	14.753	48.40	14.753	48.40
20	14.847	48.71	14.882	48.83	14.882	48.83
19	14.876	48.81	14.913	48.93	14.913	48.93
18	14.936	49.00	14.983	49.16	14.983	49.16
17	15.032	49.32	15.079	49.47	15.079	49.47
16	15.109	49.57	15.162	49.74	15.162	49.74
15	15.106	49.56	15.196	49.86	15.221	49.94
14	15.090	49.51	15.151	49.71	15.176	49.79
13	15.230	49.97	15.303	50.21	15.327	50.29
12	15.348	50.35	15.445	50.67	15.468	50.75
11	15.420	50.59	15.546	51.00	15.568	51.08
10	15.419	50.59	15.494	50.83	15.517	50.91
9	15.562	51.06	15.659	51.37	15.680	51.44
8	15.705	51.53	15.821	51.91	15.840	51.97
7	15.783	51.78	15.909	52.19	15.928	52.26
6	15.947	51.99	16.094	52.80	16.112	52.86
5	16.049	52.65	16.208	53.18	16.226	53.23
4	16.136	52.94	16.306	53.50	16.323	53.55
3	16.215	53.20	16.382	53.75	16.398	53.80

This table indicates that (a) in cases 1 and 2, water-level difference at a point closely upstream of the bridge (Section No.15) is 9 cm, that is, the constriction due to the guide banks and the replacement of the inlet channel of the Dhaleswari will cause a rise of water level of 9 cm at a point closely upstream of the bridge and (b) water-level difference between case 2 and case 3 is 2.5 cm or loss of head due to piers is 2.5 cm. It must be noticed that these rises of water level are all those in case flood water is confined within embankments to be built on both river banks.

In consideration of the water level 15.221 m at Section No.15 in Case 3, we decided to take 15.25 m or 50.033 ft PWD as the design high water level at the bridge axis.

4. Guide Banks and Cross Dikes.

4.1. Guide banks.

According to the study mentioned in 2, Chapter V, guide banks were arranged as shown in Fig.8-1. Length of circular arc at the upper end of one guide bank is 1,523 m, length of straight portion is 2,735 m, length of the lower arc is 680 m and total length of one guide bank is

4,938 m or 16,200 ft. If we place another guide bank of the same shape and the same length on the opposite side, the length of the pair of guide banks amounts to 9,876 m or 32,400 ft in total. Other dimensions were also determined by the same methods as studied in 4, Chapter V.

(a) Crown height of guide bank.

Crown height of guide bank was set at 18.25 m PWD adding 3 m of freeboard to the design high-water level.

(b) Crown width.

Crown width of guide bank was set at 10 m.

(c) Gradient of slope face.

Gradient of river-side face was set at 1 : 3 and that of land-side face was set at 1 : 2. But the latter shall be 1 : 3 as a whole including berms on the face.

(d) Apron.

Lowering of river bed between the pair of guide banks and water depth at thalweg between the guide banks were calculated by the methods mentioned in 4, Chapter V. The calculation is shown in Table 8-4. From this table, it was found that depth at thalweg below ground level would be 37.1 m at the foot of the left guide bank and 36.1 m at the foot of the right guide bank. Based on these depths, lengths of aprons were determined as follows.

Left apron: L = 1.5 D = 55.7 m.
Right apron: L = 1.5 D = 54.2 m.

Table 8-4 Mean Depth and Thalweg Depth between Both Guide-Banks

Without guide-banks:

B (m)	B_m (m)	H_m (m)	A (m^2)
5,560	4,697	9.776	45,915

With guide banks:

B_c (m)	$B_{m,c}$ (m)	$B_{m,c}/Bm$	$(B_{m,c}/B_m)^{-0.69}$	$H_{m,c}$	H_{max} (m)
4,680	3,628	0.7724	1.195	11.682	39.719

Without guide banks

B : River width

A : Water area

H_m : Mean depth

B_m : A/H_m

With guide-banks

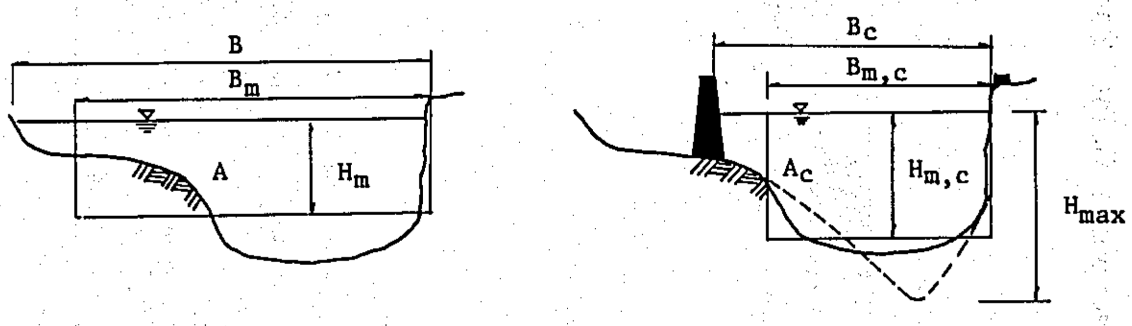
B_c : River width

A_c : Water area

$H_{m,c}$: Mean depth

$B_{m,c}$: $A_c/H_{m,c}$

H_{max} : Thalweg depth



It was decided that stone should be used for apron after study of alternative materials or methods. Thickness of the apron was set at 3 m after the idead mentioned in Chapter V.

(e) Weight of pitching stone.

Weight of pitching stone was determined at 60 to 100 kg for revetment on river-side face and 30 to 70 kg for aprons according to the study in Chapter V.

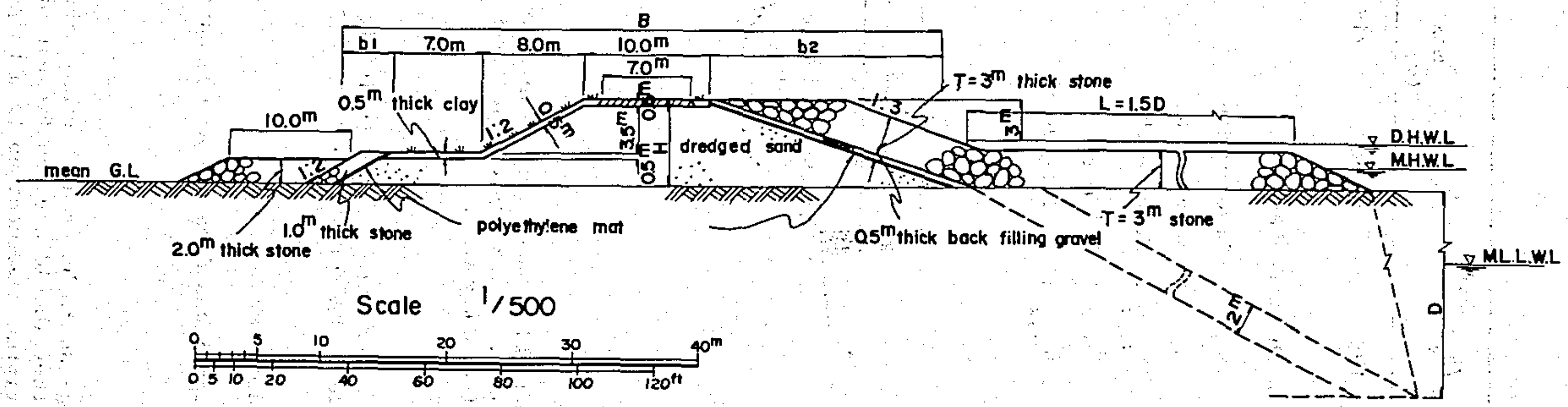
(f) Standard cross section of guide bank.

Standard cross section designed based on the above-mentioned factors is shown in Fig.8-6.

4.2. Cross dikes.

The approaches to the bridge shall be used as cross dikes. They can serve as cross dikes since they should have sufficient strength. But they shall be protected by riprap revetment up to a height of 14.0

Fig. 8-6 Standard Cross Section of Guide Banks



Dimension of Guide Banks on Bridge Axis

G.B	Water Level m (ft), PWD			Elevation m (ft), PWD			Height m (ft)		Width m (ft)			
	D.H.W.L	M.H.H.W.L	M.L.L.W.L	Crown Height	Berm	G.L	H	D	B	b1	b2	L
Left side	15.25 (50.03)	13.14 (43.11)	6.22 (20.41)	18.25 (59.88)	14.25 (46.75)	12.6 (41.34)	5.65 (18.54)	37.1 (121.72)	45.25 (148.46)	3.3 (10.83)	16.95 (55.61)	55.7 (182.74)
Right side	15.25 (50.03)	13.14 (43.11)	6.22 (20.41)	18.25 (59.88)	14.25 (46.75)	11.6 (38.06)	6.65 (21.82)	36.1 (118.44)	50.25 (164.86)	5.3 (17.39)	19.95 (65.45)	54.2 (177.82)

m PWD or 45.93 ft PWD so as to resist to flow and wave. The standard section is shown in DRW No. II-1.

4.3. Study on the material alternative to stone.

Concrete block with sufficient strength and specific weight can be used as the material alternative to stone. But it is hard to say that it is economical compared with stone to use concrete block because it needs a great amount of cement and aggregates.

It is very economical to use the soil cement block if it is possible to make the soil cement blocks by using the site sands and use them, because materials for soil cement blocks except cement can be cheaply obtained at site. But the soil cement block has defects that it is rather easy to break down and lacks in durability and the specific weight is small.

If the specific weight is small, a block shall be made bigger to be able to stand with water flow. If a block is made bigger, water flow resistance become bigger, and accordingly a block shall be made bigger that much.

On this point, assuming that the specific weight of stone is 2.65 and that of soil cement block is 1.83, eq. (6.7) in 3.2, Chapter VI shows that soil cement block about 6 times of stone in weight is necessary in place of stone. In other words, a block about 420 kg in weight is necessary for stone 70 kg in weight. Soil cement block can not be considered to be suitable as the material for this kind of river works because pitching block work so big as mentioned above is not economical compared with stone and besides soil cement block is easy to break down and lacks in durability.

Covering works with Stell Jack over the blocks was adopted to make up for these defects of soil cement block for the revetment works at Sirajganj. According to the survey result by the survey team of unit price and others dispatched in July 1975, unit construction cost of block per 100 cfs for this revetment work is about 1200 TK/ 10^2 cfc. It is not economical compared with the unit price of stone. Furthermore, the works are now under construction and it is still impossible to decide whether it is successful or not as a working method method at the present stage.

As studied above, good material alternative to stone can not be found technically and economically as the material for apron at the present stage.

But if stone is to be used for this work, a great deal of stone will be needed and stone will be needed to be imported because stone has not been produced in the country. But it is necessary to study enough before the time of execution of works, about exploitting stone in the country or a new working method which does not need stone so much, because it will be greatly economical.

5. Quantity of Works.

Quantity of the guide-bank works was calculated based upon the design shown in DRW No. II-1 and is shown in Table 8-5. Quantity of the cross dike works will be incorporated in that of the bridge approach works in Volume III BRIDGE.

Table 8-5 Quantity of Works of Guide-banks and Cross-dikes

Works		Left	Right	Total
GUIDE-BANK				
Embankment	(1,000 m^3)	727.6	692.5	1,420.0
Stone pitching	(1,000 m^3)	1,278	1,273	2.551
Placing of mat	(1,000 m^2)	112	108	220
Sodding	(1,000 m^2)	80	80	160
Crown protection	(1,000 m^2)	35	35	70
CROSS-DIKES (BRIDGE APPROACH)				
Embankment	(1,000 m^3)	2,894	3,367	6,262
Gabion (brick)	(1,000 m^3)	58.5	50.3	108.8
Placing of mat	(1,000 m^2)	42	35	77
Sodding	(1,000 m^2)	124	150.7	274.7
Slope protection (brick)	(1,000 m^2)	134.7	130.9	265.6

CHAPTER IX

TREATMENT OF THE DHALESWARI RIVER

1. Cross dam across the Dhaleswari River.

As already mentioned in 1, Chapter VIII, it was decided to cross the Dhaleswari River by a cross dam and, as a substitute therefore, to excavata a new channel connecting the Dhaleswari with the Jamuna by making use of a branch located about 6 km downstream of the bridge axis. The alignment of this new channel has already been shown in Fig.8-1.

The Dhaleswari River may easily closed, since the river almost runs out of flow in the dry season. The river shall be closed by a cross dike and road-cum-railway approach shall be banked thereon. Fig.9-1 shows a typical cross section of the cross dam. As seen in this figure, the river shall first be closed by stone dikes at both feet of the cross dike up to a height of 9.00 m PWD (29.52 ft PWD) and then the space between both stone dikes shall be reclaimed by earth up to a height of mean ground level 12.0 m PWD, on which the bridge approach shall be built.

2. New Inlet Channel of the Dhaleswari River.

The 100-year discharge of the Dhaleswari River, that is, 260,000 cfs or 7,360 cub.m/s is not the present discharge but a future discharge to be expected in case the discharge of the Old Brahmaputra is limited to 30,000 cfs and the discharge of the Jamuna is confined within both the levees. At present, without regard to this discharge, it is sufficient for the new inlet channel to secure the same water area as the present one. The water area below the average ground level is 1,400 m^2 and the mean bank-full width of the river is about 600 m. Considering these factors, standard cross section of the new channel was determined as shown in Fig.9-2. In actual construction, it will be sufficient only to dredge the central portion 300 m in width up to the depth shown in Fig.9-2.

3. Quantity of Works.

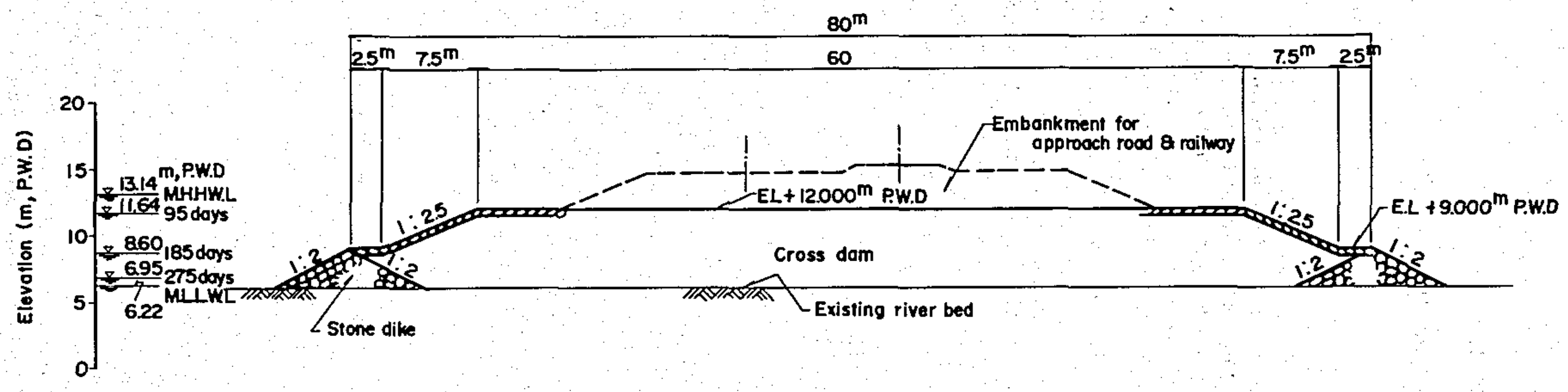
Quantity of the dredging works of the Dhaleswari New Channel is as follows.

Dredging works

Length	6 km
Quantity of earth	6,400,000 m^3
Area of land for spoil	2,970,000 m^2

Spoil shall be dumped into stream channels which will become unnecessary by dredging the new channel. Before starting the dredging works, small streams to be crossed by the new channel shall be closed by sheet piles with a view to prevent returning of spoil. The sheet piles which were employed in embankment of the guide banks

Fig. 9-1 Typical Cross Section of Cross dam (No.26 + 399) : 1 / 500



Cross Section of the Dhaleswari R.on Bridge Axis : H= 1 /5000, V= 1 / 500

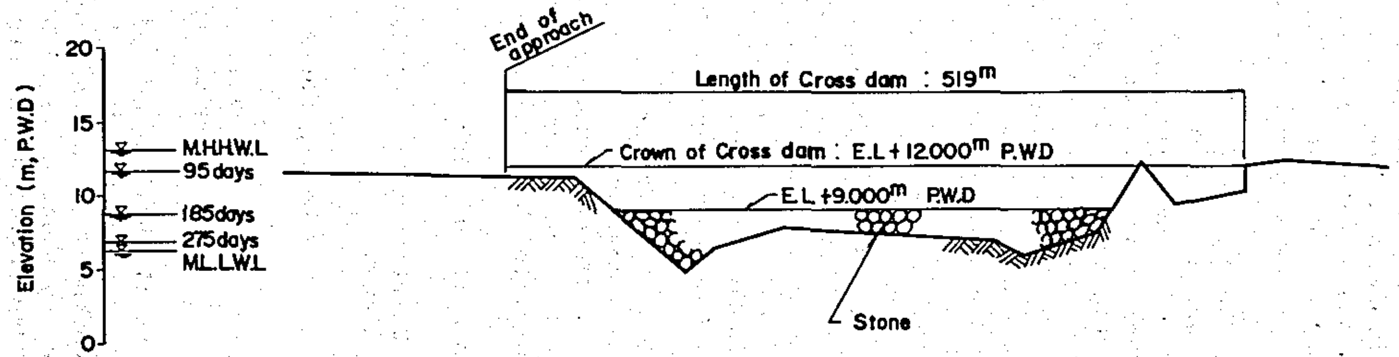
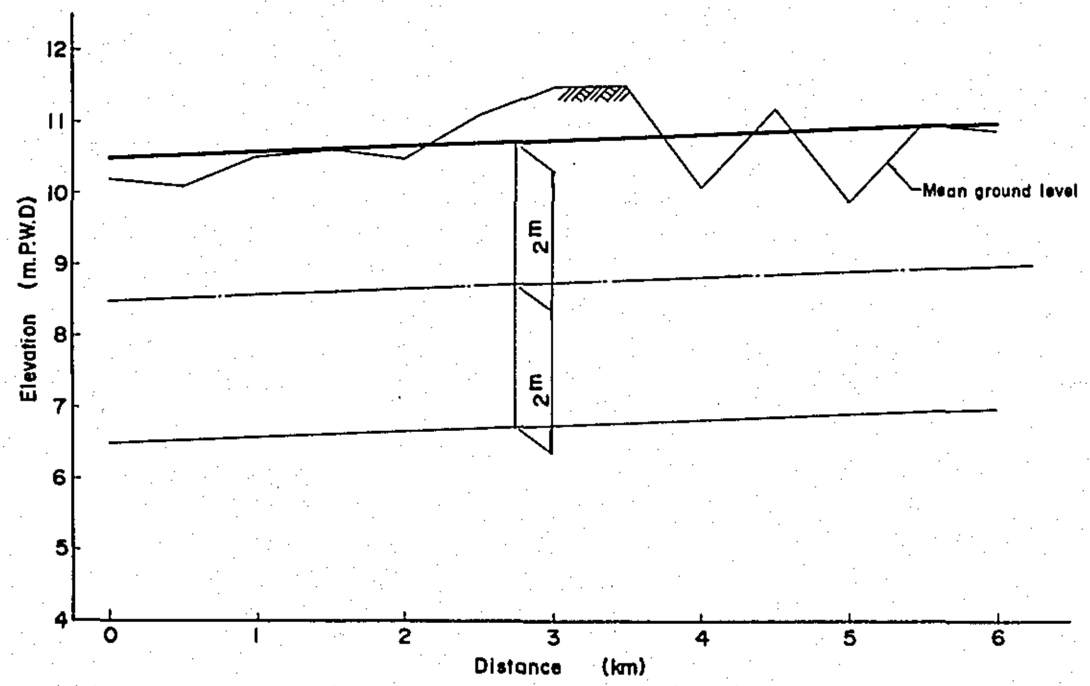
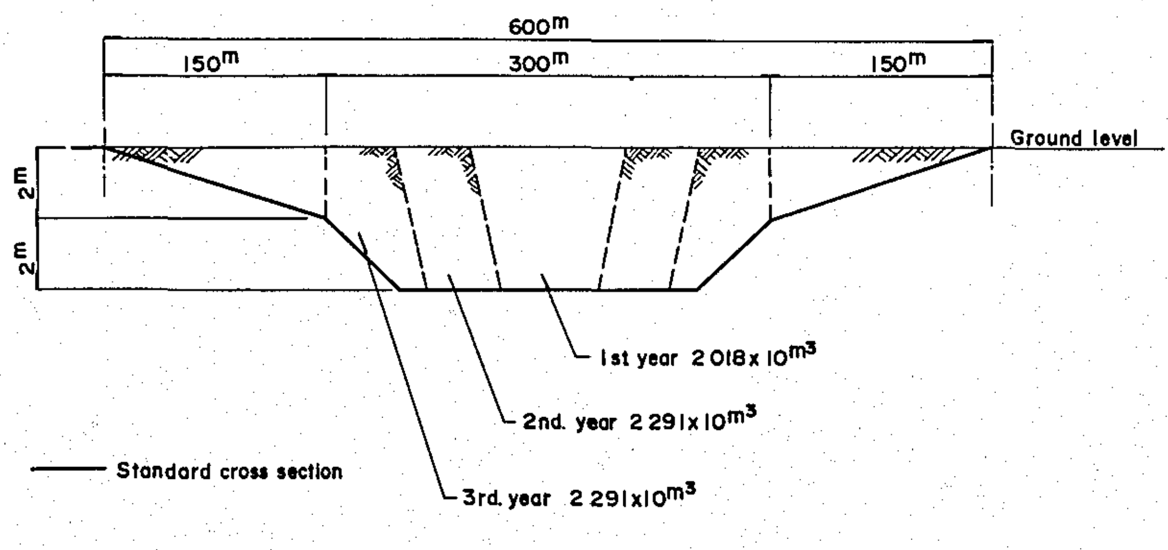


Fig. 9-2 Standard Cross Section and Profile of New Inlet Channel of the Dhaleswari





shall again be used in these closing works.

The cross dam works will consist of stone dike 350 m in length (6,500 m^3 in volume) and earth work 141,300 m^3 in volume. These works are incorporated in the bridge approach works in Volume III BRIDGE.

CHAPTER X

EXECUTION OF THE RIVER WORKS AND COSTS

1. Natural Conditions at the Work Site.

Such natural conditions at the work site as temperature, wind rainfall and water level were already mentioned in detail in 7.1, Chapter V. These were used for establishing work schedules.

2. Quantity of Works.

Quantity of guide-bank works and Dhaleswari new channel works are shown in Table 10-1, in which quantity of stone pitching work is increased by 10 % and that of earth work is increased by 20 % considering losses of those in the course of the works and shrinkage

Table 10-1 Quantity of River Works

Guide Banks

Works	Unit	Right G.B.	Left G.B.	Total	Remarks
Apron works					
Loading, transportation and unloading	10^3 m^3	1,400	1,406	2,806	Rate of increase 1.1 (including chip)
Stone pitching	10^3 m^3	1,400	1,406	2,806	
Embankment works					
Embankment	10^3 m^3	831	874	1,705	Rate of increase 1.2
Dredging	10^3 m^3	1,188	1,248	2,436	Rate of increase 10/7
Placing of mats	10^3 m^2	108	112	220	
Dike protection works					
Sodding	10^3 m^2	80	80	160	
Crown pavement	10^3 m^2	35	35	70	
Miscellaneous works					

Dhaleswari New Channel

Works	Unit	Quantity
Dredging work		
Sheet pile driving	m	3,000
Dredging	10^3 n^3	6,600
Sheet pile drawing	m	3,000
Miscellaneous works		

allowance of embankments. Construction roads for apron works form a part of the works hence the quantity of the construction roads is included in the apron works. Quantity of cross-dike works is included in the bridge approach works to be mentioned in the bridge planning.

3. Execution Schedule of the River Works.

(a) Guide banks.

Guide-bank works shall be started with the right bank. The work shall be commenced after stone of about 700,000 m^3 which is about a half of the total quantity required for one guide bank have been stocked in the right-bank stock yard by railway in a year. One guide bank shall be completed in two years; earth work and about a half of stone-pitching work shall be carried out in the first year and the remaining work shall be completed in the second year. The guide-bank works shall be shifted to the left bank after completion of the right bank. The left guide-bank works, in the same way as in the case of the right bank, shall be commenced after about a half of the total quantity of stone required for this bank have been stocked in stock yard and completed in two years. The stone for the left bank shall be transported by boats.

After all, the guide-bank works shall be completed in four years. The execution schedule of the guide-bank works is shown in Fig.10-1.

(b) Dhaleswari new channel.

Opening works of the Dhaleswari new channel shall be commenced in the year following completion of the left guide-bank and completed in three years. In order to avoid being filled up by sediment during the flood season, the new channel shall be opened in the first year over the whole length in a small width and completed by widening in the following two years. Further, in the year of commencement of the cross dam works, the left road link as well as the left bridge approach shall be completed contemplating that these structures will prevent disturbances of streams located over the area in the north of the new channel and assist the new channel to function as a floodway without being filled up by sediment. The execution schedule of the new channel works is shown in Fig.10-1.

(c) Execution schedule of the river works.

Fig.10-2 shows the whole schedule of the river works.

4. Execution of the River Works.

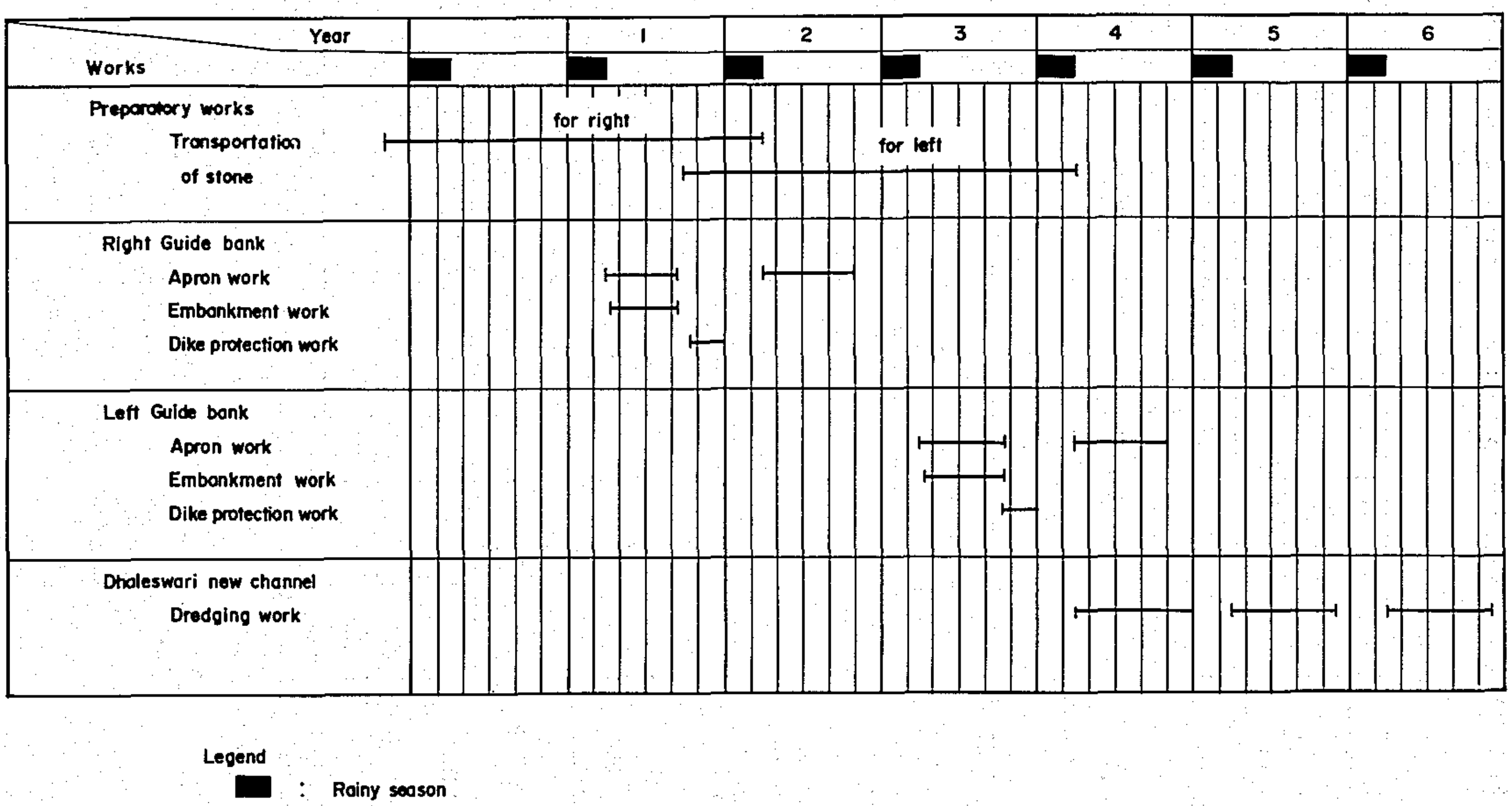
4.1. Temporary railways and temporary roads.

For the purpose of transportation of stone and other materials required for the construction works on the right bank, temporary railways shall be laid between the end of the railway link and the stone stock yard to be built near the central part of the right guide-bank. The length of the railway is about 8,400 m, alignment of which is shown in Fig.10-3.

Fig. 10-1 Execution Schedule of River Control Works

Works	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Remrks
(Working Days)	0	0	0	13	28	29	29	26	28	27	25	10	215
1st. year (Right G. B.)													
Preparatory work													
Apron work													
Embankment work													
Dike protection work													
2nd. year (Right G.B.)													
Preparatory work													
Apron work													
3rd. year (Left G.B.)													
Preparatory work													
Apron work													
Embankment work													
Dike protection work													
4th. year (Left G.B.)													
Preparatory work													
Apron work													
(D. New channel)													
Preparatory work													
Sheet pile driving work													
Dredging work													
5th. year (D.New channel)													
Preparatory work													
Dredging work													
6th. year (D. New channel)													
Preparatory work													
Dredging work													
Sheet pile driving work													

Fig. 10-2 Execution Schedule of River Works



For the purpose of communication and transportation, temporary roads shall be built from a nearest road on the right bank to the stone stock yard, from the branch construction base on the left bank to the stone stock yard on the left bank and from the branch base to the work site of the Dhaleswari new channel. Their lengths are as follows:

Temporary roads on the right bank:	3,100 m
Temporary roads on the left bank :	3,150 m
Temporary road to the new channel:	7,400 m
Total:	14,000 m (roughly)

The alignment of the temporary roads is shown in Fig.10-3.

4.2. Guide banks.

4.2.1. Embankment.

Since the construction area is submerged every flood season, banking work of one guide bank together with stone pitching work on the slope faces and a part of apron on one side shall be completed in one dry season in order to avoid losses of construction materials and works due to flood flow in the course of the construction. For this purpose, we adopted a method of banking by dredging which is capable of moving a large quantity of earth in a shortest time and at a cheapest cost.

Outline of the banking work is shown in Fig.10-4. Dredged sand will be banked in blocks which will be formed by sheet-pile partition walls. Length of a block shall be 500 m. Height of banking shall be 1.5 m at a time. For supporting the sheet-pile walls, earth shall be moved and heaped up at the back of the walls by swamp-type bulldozers. For this dredging, a 4,000-PS-class dredger was adopted taking into consideration height of banking, distance of transportation of sand and quantity of banking works. Flow of the construction works is shown in Fig.10-5 and main construction equipment for the works are as follows.

4,000-PS Diesel pump dredger.
200-PS anchor barges
15-KW vibro-pile drivers (drawer).
20-ton crawler cranes.
125-KVA engine dynamos.
16-ton swamp-type bulldozers.

4.2.2. Stone pitching works.

River banks seldom retreat more than 500 m in a year. In consideration of this fact, the alignment of the guide banks was planned to keep distance of about 500 m from bank edge and stone pitching works of one guide bank were planned to be completed in two years. Accordingly, stone pitching works in the first year shall be done simultaneously with banking works. For these works, about a half of total quantity of stone required for one guide bank shall be spent.

The stone pitching works shall be completed in the second year using the remainder of stone.

Fig.10-6 shows horizontal arrangement and cross section of construction roads for guide bank work. They are planned as one-way roads located along apron part of guide bank. The first layer shall be built with 0.5 m-thick stone chip. The road shall be raised by 0.5 m with the progress of apron construction and shall be switched to new ones which shall be built beside the preceding ones. The second and subsequent layers shall be built with stone and filling-up chip. Thus, every new road shall be built 0.5 m higher than the preceding one.

Stone pitching shall be carried out by loading in the stock yards by tractor shovels, carrying by heavy-duty dump trucks and pitching by man power. The number of workers for pitching was counted assuming that the maximum carriage distance by manpower is 40 m, one unit of workers consists of 20 persons and the units are distributed on the pitching area as uniformly as possible. Further, tiredozers of 19-ton-class were added for assisting manpower pitching. Principal machinery required for stone pitching is as follows.

Loading:	5 m^3 wheel-type tractor shovels.
Carrying:	32-ton heavy-duty dump trucks.
Pitching:	Manpower.
	19-ton tiredozers.

4.3. Cross dikes.

Execution of cross-dike works is mentioned in Volume III BRIDGE.

4.4. Cross dam and Dhaleswari new channel.

4.4.1. Cross dam.

Stone dikes of the cross dam shall be built with stone transported by 32-ton heavy-duty dump trucks in the first year of the bridge approach works. In this case, the dump trucks used in guide-bank works shall again be used and pitching of stone shall be carried out by manpower. After completion of stone dikes, banking shall be carried out by the same method as approach construction works. Plan of the works is included in the bridge approach works in Volume III. Principal machinery required for the stone pitching work is as follows.

Loading:	5 m^3 wheel-type tractor shovels.
Carrying:	32-ton heavy-duty dump trucks.
Pitching:	Manpower

4.4.2. Dhaleswari new channel.

Construction of Dhaleswari new channel shall be carried out by the dredger which was used in the guide-bank works. As seen in Fig.9-2, a center channel 65 m in bottom width shall be opened over the whole length in the first year and shall be completed in the third year after widening the width in two years. Spoil shall be dumped in adjacent

Fig. 10-3 Location of Guide banks, Temporary Railways, Temporary Roads, Construction Base and Stone Stock Yard

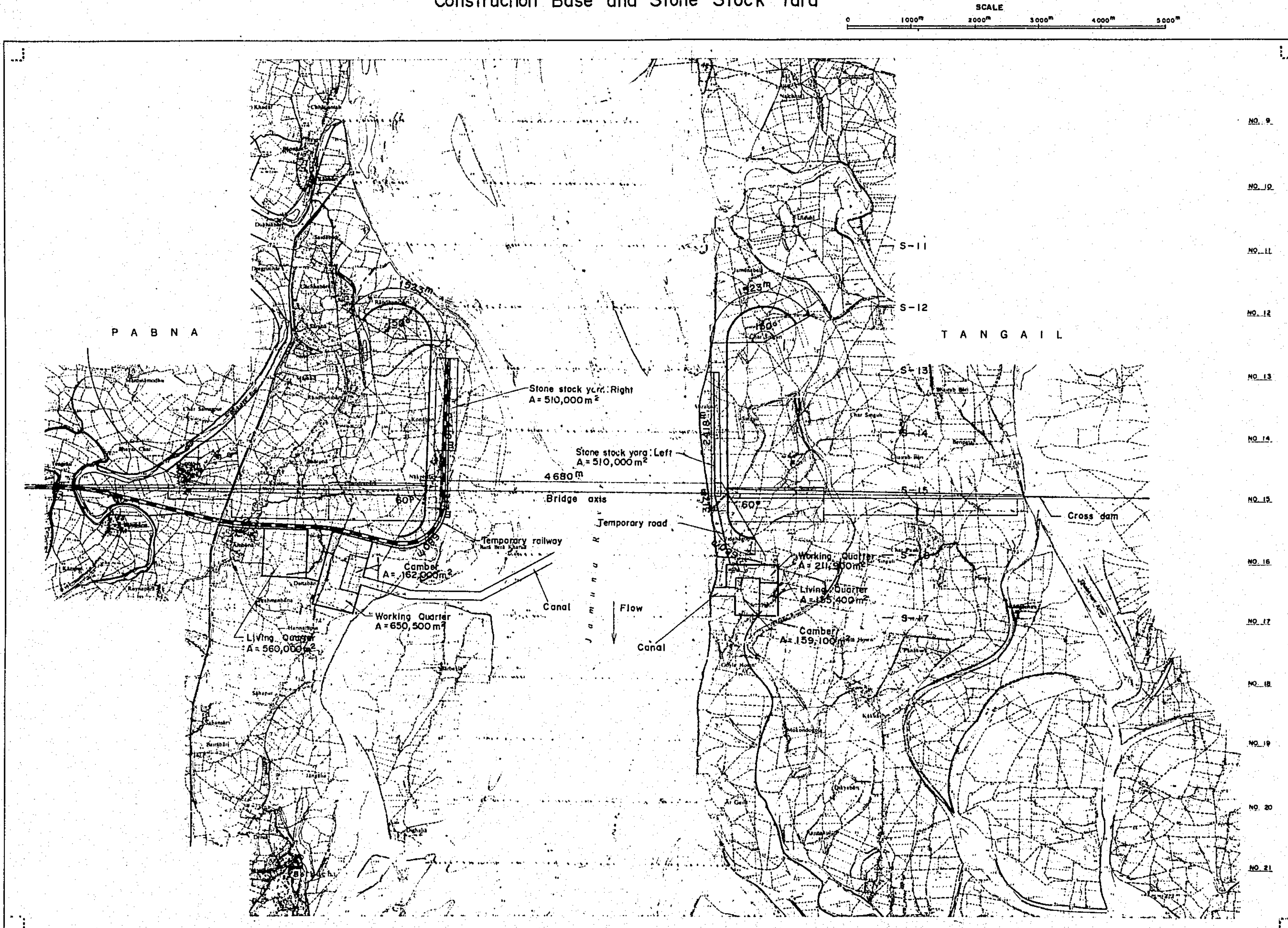


Fig. 10-3 Location of Guide banks, Temporary Railways, Temporary Roads, Construction Base and Stone Stock Yard

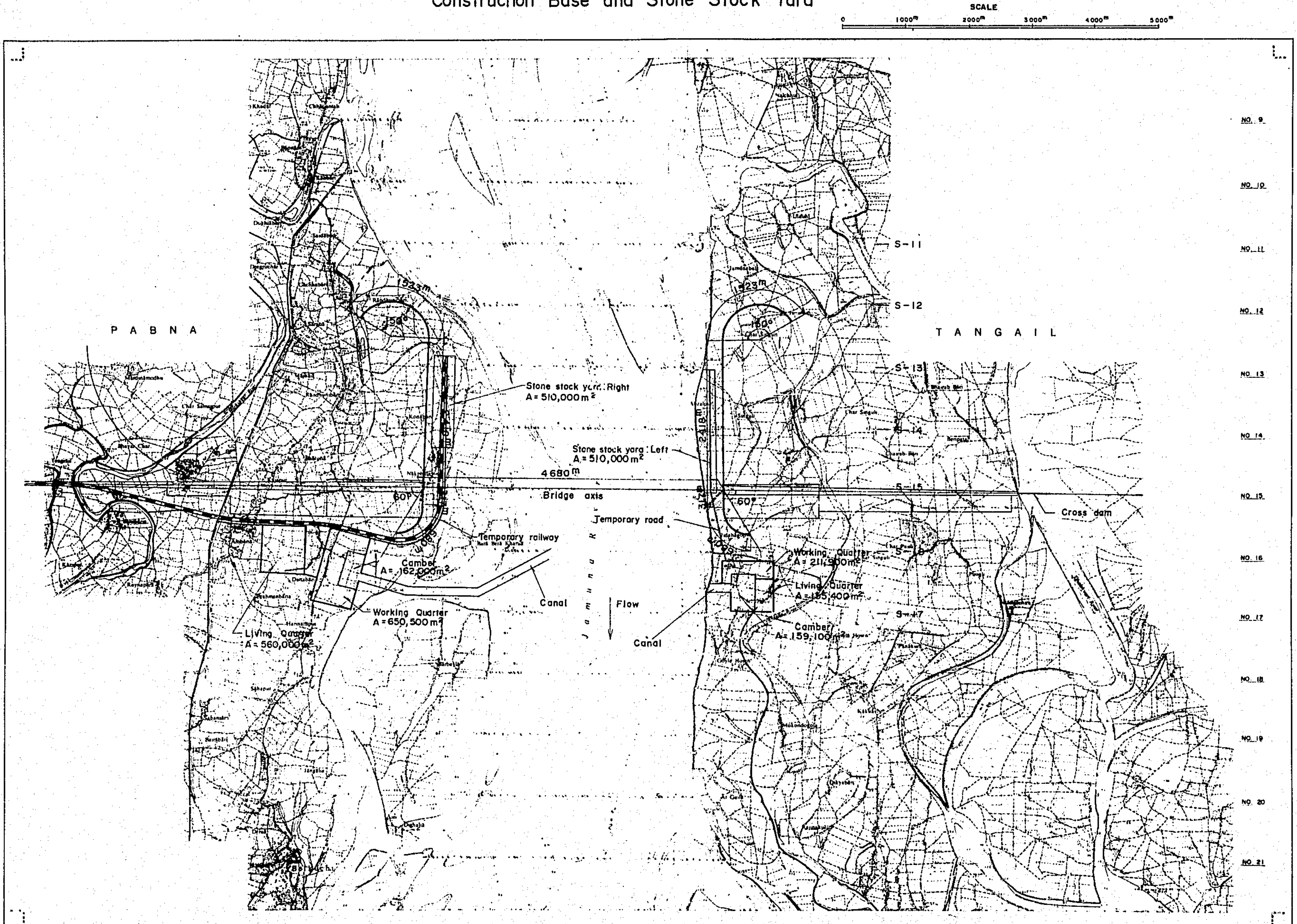
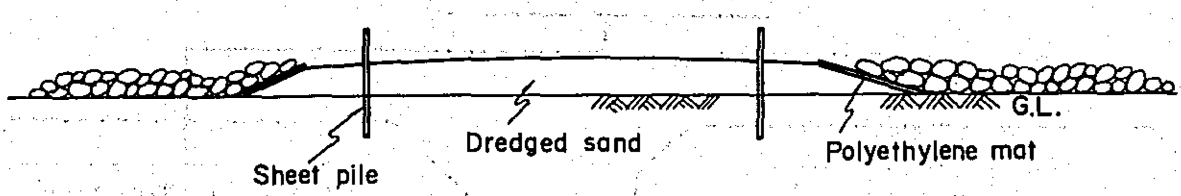
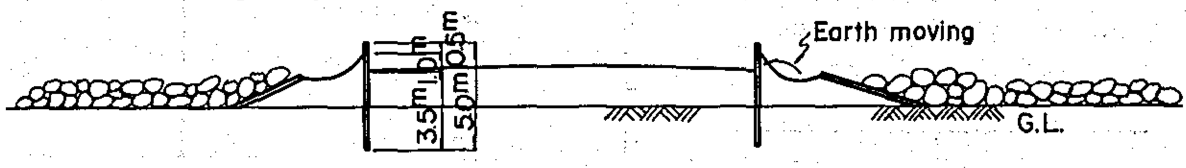


Fig. 10-4 Schematic View of Banking Work

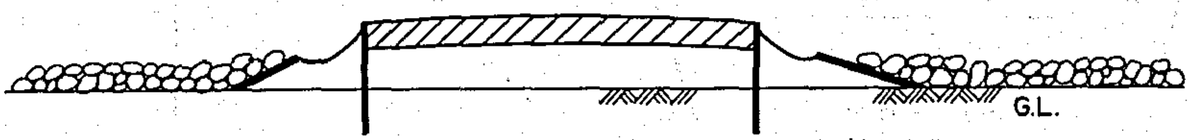
(1) Sheet pile driving



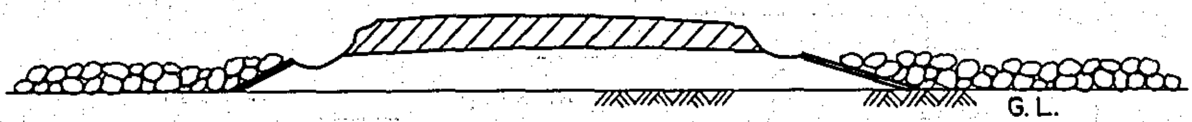
(2) Banking againist the back of sheet pile walls



(3) Dredging, banking and drying-up



(4) Sheet pile drawing



(5) Polyethylene mat and filling-up chips

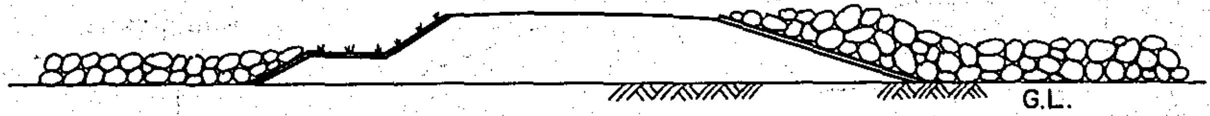


Fig. 10-5 Flow of Construction Works of Guide Banks

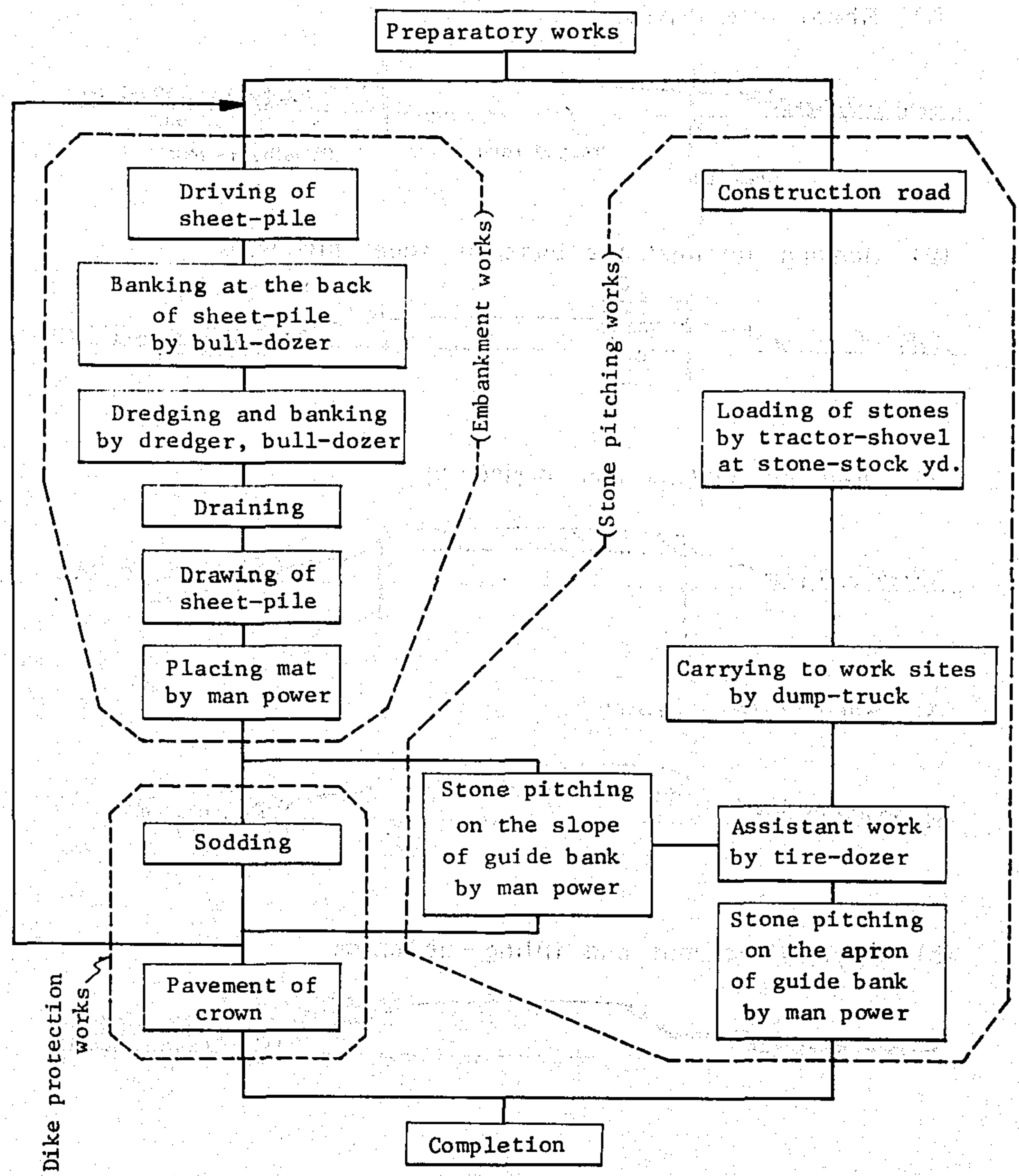
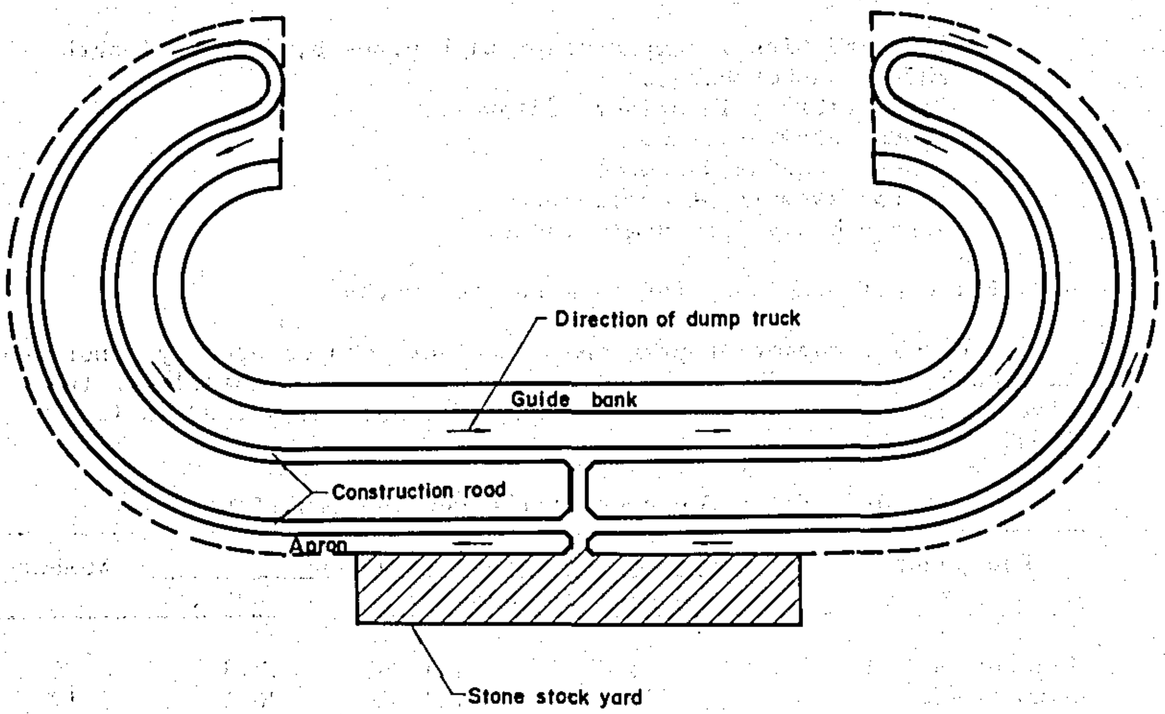
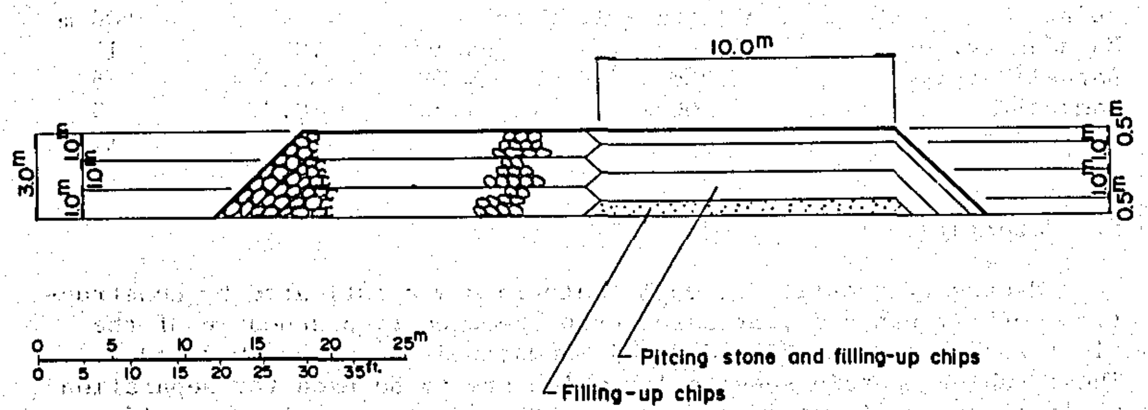


Fig. 10-6 Construction Roads

Construction Road Schelton



Cross Section



depressions of 2,970,000 m^2. Swamp-type bulldozers shall be provided as assistant machinery for the dredging works. In dumping spoil, sheet-pile walls shall be used for separating the depressions from Dhaleswari new channel and swamp-thpe bulldozers shall also be used as assistant machinery. Principal machinery required for the works is as follows.

4,000-PS Diesel pump dredger with pipes 6,000 m in length.
200-PS anchor barge.
15-KW vibro-pile drivers (drawer).
20-ton crawler cranes.
125-KVA engine dynamos.
16-ton swamp-type bulldozers.
32-ton heavy-duty dump trucks.

4.5. Principal machinery for construction works.

Necessary number of principal machinery was counted by construction work, month and year based upon the execution schedule of the river construction works shown in Fig.10-2 and summarized in Table 10-2.

Table 10-2 Major Equipment for River Construction Works

Equipment	Specification			Number
	Capacity	Rated H.P.	Weight (t)	
Tractor shovel	5 m^3	325 PS	29.9	5
Damp truck	32 t	427 PS	26.1	17
Tire dozer	19 t	200 PS	18.9	5
Bull dozer (swamp)	16 t	140 PS	16.2	8
Vibro pile driver	15 kw	15 kw	1.1	68
Crawler crane	20 t	98 PS	26.5	68
Sheet pile	1 = 5 m	b = 0.333 m(1,235 t)	0.074	5,550 m
Engine dynamo	125 kvA	160 kw	3.1	18
Diesel pump dredger	4,000 PS	4,000 PS		1
Anchor barge	15 t	200 PS		1
Pipe	1 = 5 m D = 710 mm (1,000 sets)			6,000 m
Floater	1 = 4.5 m D = 1,300 mm (268 sets)			1,210 m
Joint	1 = 1.5 m (266 sets)			400 m
Macadam roller	10 - 12 t	65 kw	10	15
Asphalt sprayer	200 1	4 PS	0.2	6
Tamper	60 kg	4 PS	0.08	5
Spare parts				1.s.

5. Materials.

Necessary quantity of major materials was estimated by construction work, month and year based upon the execution schedule of the river works shown in Fig.10-2 and summarized in Tables 10-3 and 4. These tables contain sheet piles which are to be used for separation walls of the Dhaleswari new channel after employment in the guide-bank works.

Table 10-3 Materials Required for River Construction Works (1)

Guide banks

Materials	Unit	Right G.B.	Left G.B.	Total
Apron works				
Stone	10^3 m^3	1,400	1,406	2,806
Light oil	kl	1,345	1,368	2,713
Miscellaneous		l.s.	l.s.	l.s.
Embankment works				
Log	m^3	1,073	1,100	2,173
Polyethylene mat	10^3 m^2	119	123	242
Light oil	kl	734	734	1,468
Heavy oil	kl	1,680	1,764	3,444
Miscellaneous		l.s.	l.s.	l.s.
Dike protection works				
Sodding	10^3 m^2	88	88	176
Ballast (chip)	10^3 m^3	30	30	60
Asphalt emulsion	kl	305	305	610
Light oil	kl	81	81	162
Miscellaneous		l.s.	l.s.	l.s.

Dhaleswari new Channel

Materials	Unit	Quantity
Sheet pile driving work		
Light oil	kl	44
Miscellaneous		l.s.
Dredging		
Light oil	kl	298
Heavy oil	kl	9,341
Log	m^3	396
Miscellaneous		l.s.
Sheet pile drawing work		
Light oil	kl	34
Miscellaneous		l.s.

Table 10-4 Materials Required for River Construction Works (2)

Materials	Unit	Right G.B.	Left G.B.	Dhaleswari	Total
Stone	10^3 m^3	1,400	1,406		2,806
Sand	10^3 m^3	831	874		1,705
Polyethylene mat	10^3 m^2	119	123		242
Log	m^3	1,073	1,100	396	2,569
Light oil	kl	2,160	2,183	376	4,719
Heavy oil	kl	1,680	1,764	9,341	12,785
Sod	10^3 m^2	88	88		176
Ballast (chip)	10^3 m^3	30	30		60
Asphalt emulsion	kl	305	305		610
Miscellaneous		l.s.	l.s.	l.s.	l.s.

6. Labor

Number of skilled labour and unskilled labour was counted by construction work, month and year based upon the execution schedule of the river work shown in Fig.10-2, and daily maximum number of labor is listed in Table 10-5 by skilled, unskilled and year, in which miscellaneous labor is not included.

Table 10-5 Daily maximum Number of Labor at Work Sites

	1st year	2nd year	3rd year	4th year	5th year	6th year
Skilled	2,090	150	2,090	300	120	120
Unskilled	2,215	2,205	2,210	2,210	0	0

7. Major Facilities Required for Managing the River Works.

A construction office shall be built in the main construction base on the right bank, sub-offices shall be put at work sites and control offices shall be put in the stone stock yards. Sub-offices are for controling the guide-bank works and the Dhaleswari new channel works.

Construction office in the main construction base.

Plottage 2,000 m^2

Floorage 300 m^2

Three sub-offices for right guide-bank, left guide-bank and Dhaleswari new channel.

Plottage 6,000 m^2

Floorage 900 m^2

Two control offices in the stone stock yards.

Plottage	1,600 m^2
Floorage	400 m^2

Communication system, cars and other facilities are required for the above offices.

As shown in Fig.10-3, stone stock yards shall be put near the central part of the guide-banks. Each stock yard shall be provided with a plottage required for storing 700,000 m^3 in a year. On the right bank, stone shall be carried in by railway; and on the left bank, by boat. Polyethylene mat shall also be stored in the stone stock yards. Other miscellaneous materials and machinery shall be stored in warehouses to be built in the stone stock yards. Area required for the stock yards and floorage of the warehouses are as follows.

Area of the stock yards	510,000 m^2 each.
Floorage of the warehouses	800 m^2

Motor-pools required for construction of guide-banks shall be put on the both banks of the river. The motor-pool for the left guide-bank works shall also be used for the opening works of the Dhaleswari new channel.

Detailed plan for the above-mentioned facilities will be incorporated in Volume VIII OVERALL CONSTRUCTION PLAN AND ECONOMIC ANALYSIS.

8. Costs.

8.1. Unit Prices.

In estimating the costs of the river works, unit prices of materials, equipment and labor to be procured locally and to be imported from abroad were set based on the results of surveying of the Price Survey Team (143CS) which was organized by the JICA in July 1975. Accordingly the costs estimated in this report are those as of July 1975.

Besides the materials mentioned above, purchase plan of pitching stone was made as shown in Table 10-6 based on the results of surveying of the Stone Material Survey Team (Feasibility Report Volume VI GEOLOGY AND STONE MATERIAL). For estimating the cost of stone pitching works was used the weighted-mean unit price of stone to be collected from Manikarchar, Dhubri, Jagioghopa, Dhulian and Pakur of India.

We assumed that import and excise taxes will not be imposed upon the materials and equipment to be imported for this project. The unit prices which were used in this report are summarized in Table 10-7, in which the unit prices of oils, lubricants and asphalt emulsion are given in CIF prices and inland transportation costs which were estimated on the basis of breakdown of the local prices but polyethylen mat price is given in CIF price added FOB price to transportation cost and inland transportation cost.

Table 10-6 Purchase Plan of Pitching Stone

	Unit	Sources of stone in India					Total
		Assam			Bihar		
		Manikarchar	Dhubri	Jagioghopa	Dhulian	Pakur	
Transportation		by boat	by boat	by boat	by boat	by train	
Quantity required per annum	Tk/yr	162,540	141,750	124,740	378,000	900,000	1,707,030
	10^2cft/yr	32,508	28,350	24,948	75,600	180,000	341,406
Unit price F O B	Tk/10^2cft	390	243	165	312	234	
Annual cost F O B	Tk/yr	12,687,120	6,889,050	4,116,420	23,587,200	42,120,000	89,399,790
Unit Price at site	Tk/10^2cft	570	453	404	645	391	
Annual cost at site		18,529,560	12,842,560	10,078,992	48,762,000	70,380,000	160,593,103

Mean unit price;

$$\text{F O B} : \frac{89,399,790}{34,140,600} = 262 \text{ Tk}/10^2\text{cft}$$

$$\text{At site} : \frac{160,593,102}{34,140,600} = 470 \text{ Tk}/10^2\text{cft}$$

Table 10-7 Unit Price

1. Wages.

Labor	$/day	Tk/day
Skilled labor		
Operator 1 (Crawler crane)	66.5	45
Operator 2	66.5	28
Assistant operator (Crawler crane)	44.8	
Driver	60.8	28
High class crew	110	
Crew	81.8	
Special skilled labor	70.2	
Skilled labor	62.7	23
Foreman	66.5	45
Unskilled labor		17

2. Materials

Item	Unit	FOB	Transportation Tk	At site Tk
Stone and chip	100 cft	*20.15 (Tk 262)	208	470
Light oil	IG	*0.2815(Tk 3.66)	0.80	4.46
Lublicants	IG	*3.255 (Tk 42.31)	1.93	44.24
Heavy oil	IG	*0.2892(Tk 3.76)	0.88	4.64
Polyethylene mat	m^2	2.967		
Asphalt emulsion	kl	*115.4 (Tk 1500)	194	1694
Log	cft			90
Sod	100 ft			8

Note: IG = Imperial gallon

* = C I F

3. Land acquisition 1 acre Tk 12,000

8.2. Costs of river control works including Dhaleswari new channel works.

Costs of the river control works including the opening works of Dhaleswari new channel were calculated on the basis of the unit prices mentioned above. These are shown in Table 10-8. The costs required for cross-dike works and cross dam crossing the Dhaleswari River are incorporated in the costs of bridge construction as a part of the bridge approaches.

It was decided to import all the equipment required for the river control works. For estimation of the construction costs were used the CIF price which was added the transportation cost to FOB price to be planned in a lump of the equipment. Also cost of inland transportation were estimated as to be carried out by water channel from the Chalna port to the site.

Table 10-9 shows breakdown of the labor costs given in Table 10-8. Table 10-10 shows breakdown of the purchase costs of the equipment and Table 10-11 breakdown of the costs of materials.

The annual costs of construction are shown in Table 10-12-1 and Table 10-12-2, which were estimated on basis of the work schedule of the Table 10-2.

8.3. Maintenance costs.

Maintenance costs for the river facilities will contain those required for inspection, surveying, repair of the guide banks, maintenance of the Dhaleswari new channel and management including maintenance of offices. Therefore, the maintenance costs, together with those required for the bridge, will be dealt with in Volume VIII OVERALL CONSTRUCTION PLAN AND ECONOMIC ANALYSIS.

Table 10-8 Construction Costs of Guide-banks and New Channel

Works	Unit	Quantity	Costs Local	Costs Foreign	Costs Total
			10^3Tk	10^3\$	10^3Tk
(1) Right guide-bank					
Apron	10^3m^3 (10^3cft)	1,400 (49,435)	118,450	11,933	273,579
Embankment	10^3m^3 (10^3cft)	831 (29,343)	4,756	14,345	191,241
Dike protection	10^3m^2 (10^3cft)	Sodding 80(861) Pavement 35(377)	3,985	254	7,287
Miscellaneous			6,357	1,315	23,452
Subtotal			133,548	27,847	495,559
(2) Left guide-bank					
Apron	10^3m^3 (10^3cft)	1,406 (49,647)	119,140	11,947	274,451
Embankment	10^3m^3 (10^3cft)	874 (30,862)	4,867	14,366	191,625
Dike protection	10^3m^2	Sodding 80(861) Pavement 35(377)	3,985	255	7,300
Miscellaneous			6,397	1,319	23,544
Subtotal			134,389	27,887	496,920
(3) Dhaleswari new channel					
Sheet pile	m (ft)	3,000 (9,843)	17	572	7,453
Dredging	10^3m^3 (10^3cft)	6,600 (233,051)	3,697	4,325	59,922
Miscellaneous			186	245	3,371
Subtotal			3,900	5,142	70,746
Total (1)+(2)+(3)			271,837	60,876	1,063,225
(4) Equipment			1,807	16,216	212,615
Total (1)+(2)+(3)+(4)			273,644	77,092	1,275,840
(5) Land acquisition					
Right guide-bank	acre	157	1,883		1,883
Left guide-bank	acre	151	1,812		1,812
Dhaleswari new channel	acre	900	10,799		10,799
Subtotal			14,494		14,494
Grand total			288,138	77,092	1,290,334

1\$ = 13 Tk

Table 10-9 Labor Cost

Works	Description	Person No. (m.d)		Amount (10^3)
Right guide-bank				
Apron	Skilled	29,620	Tk	1,210
	Unskilled	877,500	Tk	14,930
	Foreign	29,620	$	1,946
	Subtotal	936,740	Tk	41,430
Embankment	Skilled	28,700	Tk	670
	Unskilled	680	Tk	10
	Foreign	210,690	$	14,430
	Subtotal	240,070	Tk	188,270
Dike protection	Skilled	35,990	Tk	940
	Unskilled	45,980	Tk	780
	Foreign	-	$	-
	Subtotal	81,970	Tk	1,720
Total	Skilled	94,310	Tk	2,820
	Unskilled	924,160	Tk	15,720
	Foreign	240,310	$	16,376
	Total	1,258,780	Tk	231,420
Left guide-bank				
Apron	Skilled	30,090	Tk	1,230
	Unskilled	891,540	Tk	15,170
	Foreign	30,090	$	1,977
	Subtotal	951,720	Tk	42,090
Embankment	Skilled	28,700	Tk	670
	Unskilled	710	Tk	10
	Foreign	210,690	$	14,420
	Subtotal	240,100	Tk	188,270
Dike protection	Silled	35,990	Tk	930
	Unskilled	45,980	Tk	780
	Foreign	-	$	-
	Subtotal	81,970	Tk	1,720
Total	Skilled	94,780	Tk	2,830
	Unskilled	938,230	Tk	15,960
	Foreign	240,780	$	16,406
	Total	1,273,790	Tk	232,070
Dhaleswari new channel				
Sheet pile	Skilled	-	Tk	-
	Unskilled	-	Tk	-
	Foreign	8,700	$	595
	Subtotal	8,700	Tk	7,730
Dredging	Skilled	25,020	Tk	600
	Unskilled	-	Tk	-
	Foreign	51,180	$	3,895
	Subtotal	76,200	Tk	51,230
Total	Skilled	25,020	Tk	600
	Unskilled	-	Tk	-
	Foreign	59,880	$	4,490
	Total	84,900	Tk	58,970
Grand total	Skilled	214,110	Tk	6,250
	Unskilled	1,862,390	Tk	31,680
	Foreign	504,970	$	37,272
	Grand total	2,617,470	Tk	522,470

Including miscellaneous work (5%)

Table 10-10 Cost of Equipment

Equipment	Quantity	Unit price ($)	Costs F.C. (10^3\$)	Costs D.C. (10^3Tk)
Tractor shovel (5 m^3)	6	167,800	1,007	-
Dump truck (32t)	19	135,800	2,756	-
Tire dozer (19t)	6	66,000	396	-
Bull dozer (16t, swamp)	9	63,390	571	-
Vibro pile driver (15 kw)	73	8,645	631	-
Crawler crane (20t)	73	59,660	4,355	-
Sheet pile (l=5m, b=0.333m)	1,355t	267	356	-
Engine dynamo (125kvA)	20	20,000	400	-
Diesel Pump dredger (4,000PS)	1	accounted in construction base works		
Anchor barge (15t)	1	-do-		
Dredging pipe (ϕ710mm, 5m)	500sets	808	404	-
Floater (ϕ1,300mm, 4.5m)	134sets	3,630	486	-
Joint (1-1.5m, rubber)	500sets	1,400	186	-
Macadam roller (10-12t)	16	20,700	331	-
Asphalt sprayer (200 l)	7	1,220	9	-
Tamper (60kg)	6	495	3	-
Spare parts and others (30% above)			3,568	-
Total amount in FOB price			15,459	-
Total amount in CIF price			16,216	1,807

Notes: These equipments are used for the guide-bank works and some of them are applied for the Dhaleswari new channel works.

Table 10-11 Cost of Materials

Item	Quantity Unit	Quantity	Cost D.C. (10^3Tk)	Cost F.C. (10^3\$)	Remarks
GUIDE BANK WORKS					
Domestic materials					
Log	m^3	2,173	6,902	-	
Sod	10^3m^2	176	150	-	
Miscellaneous	l.s.	1	353	-	
Total			7,405	-	
Foreign materials					
Stone	10^3m^3	2,806	206,090	19,969	
Ballast (chip)	"	60	4,410	427	
Light oil	Kl	4,341	764	269	
Heavy oil	"	3,444	665	219	
Lubricants	l.s.	1	153	54	
Asphalt emulsion	Kl	610	118	70	
Polyethylene mat	10^3m^2	242	-	718	FOB
Miscellaneous	l.s.	1	10,522	1,080	
Subtotal of CIF			222,722	22,052	
Subtotal of FOB			-	752	
CIF cost for above			480	900	
Total			223,202	22,952	
Grand Total			230,607	22.952	
DHALESWARI NEW CHANNEL WORKS					
Domestic materials					
Log	m^3	396	1,258	-	
Miscellaneous	l.s.	1	63	-	
Total			1,321	-	
Foreign materials					
Light oil	Kl	378	66	23	
Heavy oil	"	9,341	1,805	594	
Lubricants	l.s.	1	13	5	
Miscellaneous	l.s.	1	95	30	
Total			1,979	652	
Grand Total			3,300	652	

Table 10-12-1 Construction Cost by Year

Works: Guide Banks

Outline of works: Embankment, stone pitching, sodding, pavement and miscellaneous.

Year	Equipment		Materials		Labor			Total	
					Skilled		Unskilled		
	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	D.C. (10^3Tk)	F.C. (10^3\$)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1st.									
2nd.									
3rd.									
4th									
5th									
6th	1,807	16,216	53,997	5,655				55,804	21,871
7th			60,850	5,733	2,180	15,360	7,930	70,960	21,093
8th			54,790	5,784	630	1,016	7,790	63,210	6,800
9th			60,820	5,729	2,210	15,394	8,190	71,220	21,123
10th			150	51	630	1,012	7,770	8,550	1,063
11th									
12th									
13th									
Total	1,807	16,216	230,607	22,952	5,650	32,782	31,680	269,744	71,950

Table 10-12-2 Construction Cost by Year

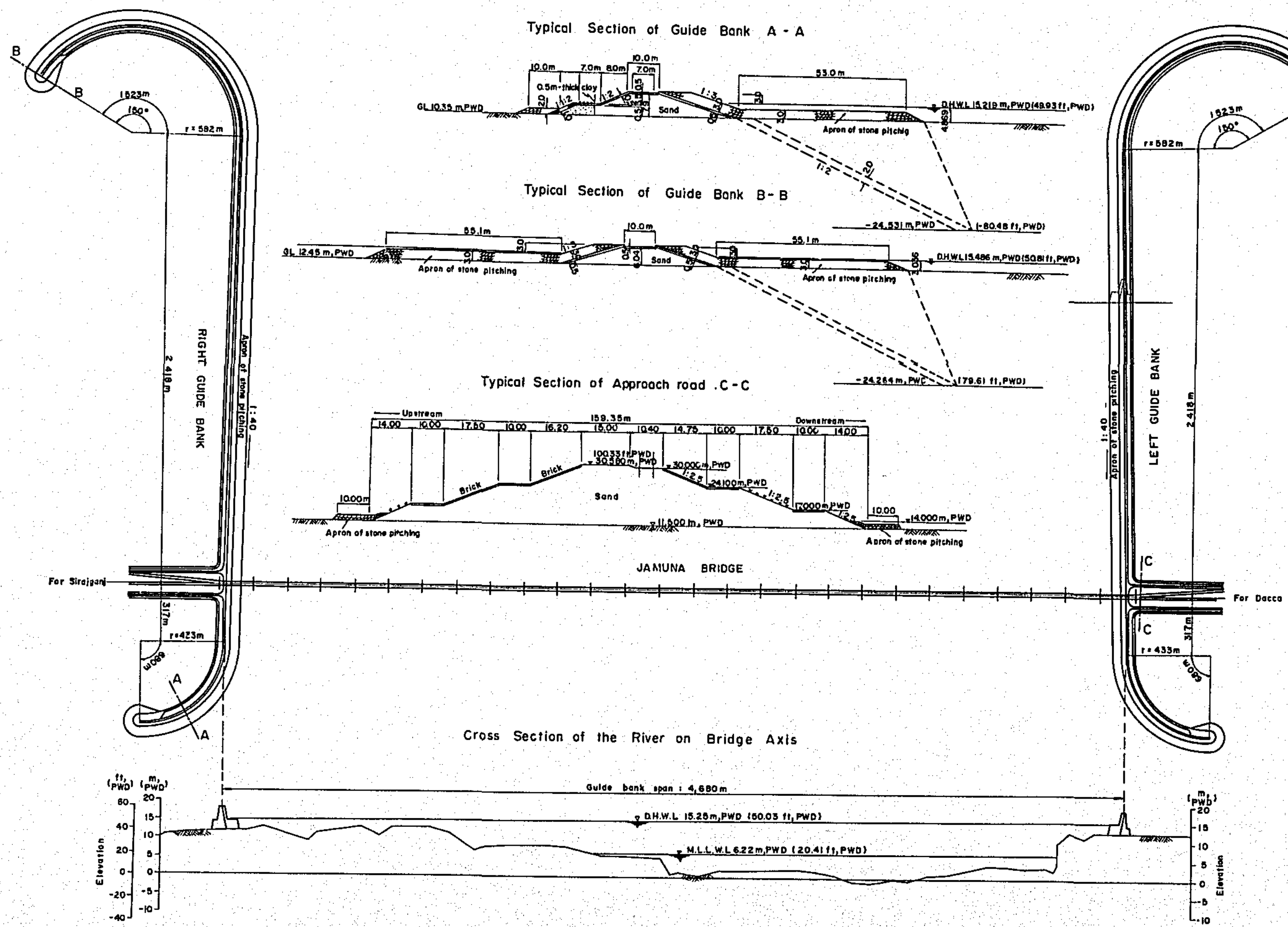
Works: Dhaleswari New Channel

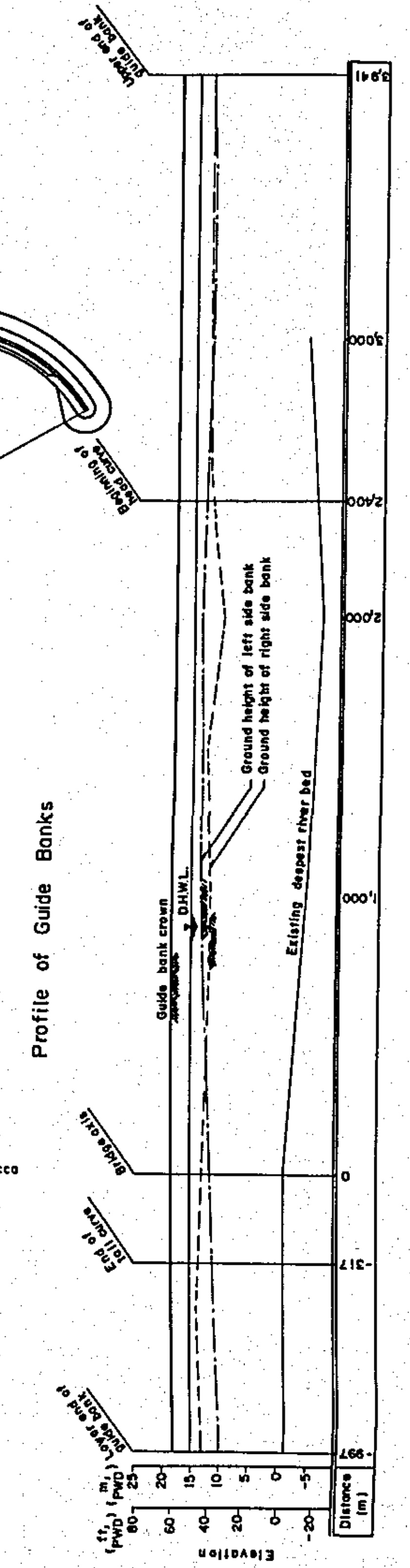
Outline of works: Dredging and miscellaneous.

Year	Equipment		Materials		Labor			Total	
					Skilled		Unskilled		
	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	D.C. (10^3Tk)	F.C. (10^3\$)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1st.									
2nd.									
3rd.									
4th									
5th									
6th									
7th									
8th									
9th									
10th			1,050	201	200	1,569		1,250	1,770
11th			1,120	225	200	1,334		1,320	1,559
12th			1,130	226	200	1,587		1,330	1,813
13th									
Total			3,300	652	600	4,490		3,900	5,142

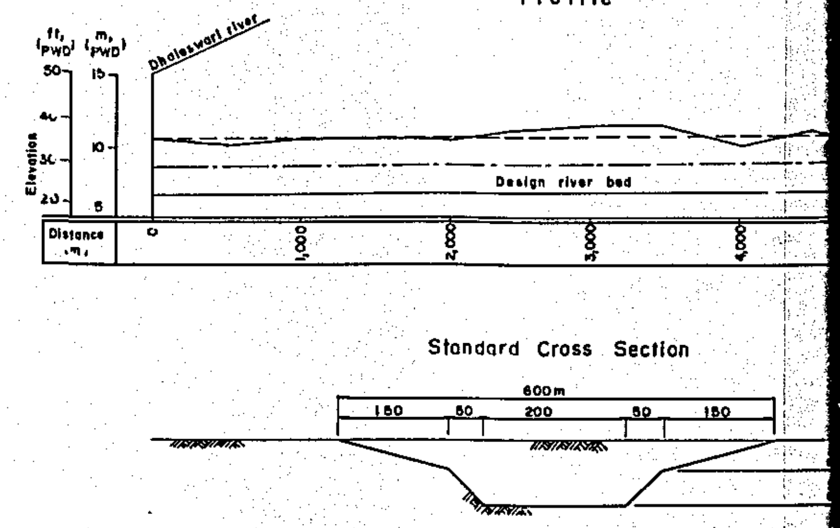
APPENDICIES

General Plan of Guide Banks and Bridge

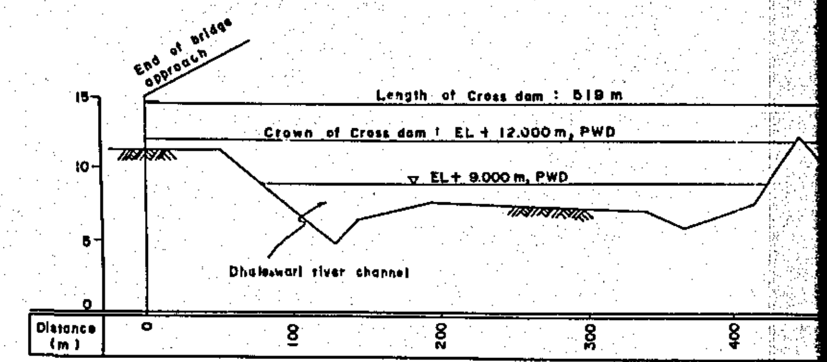


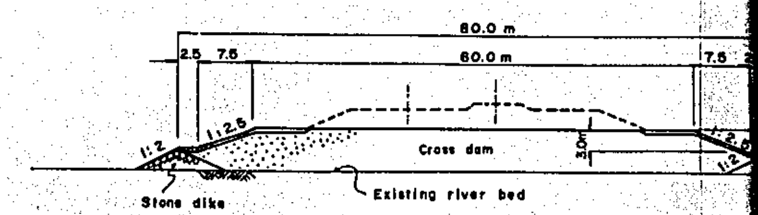


Dhaleswari New Channel

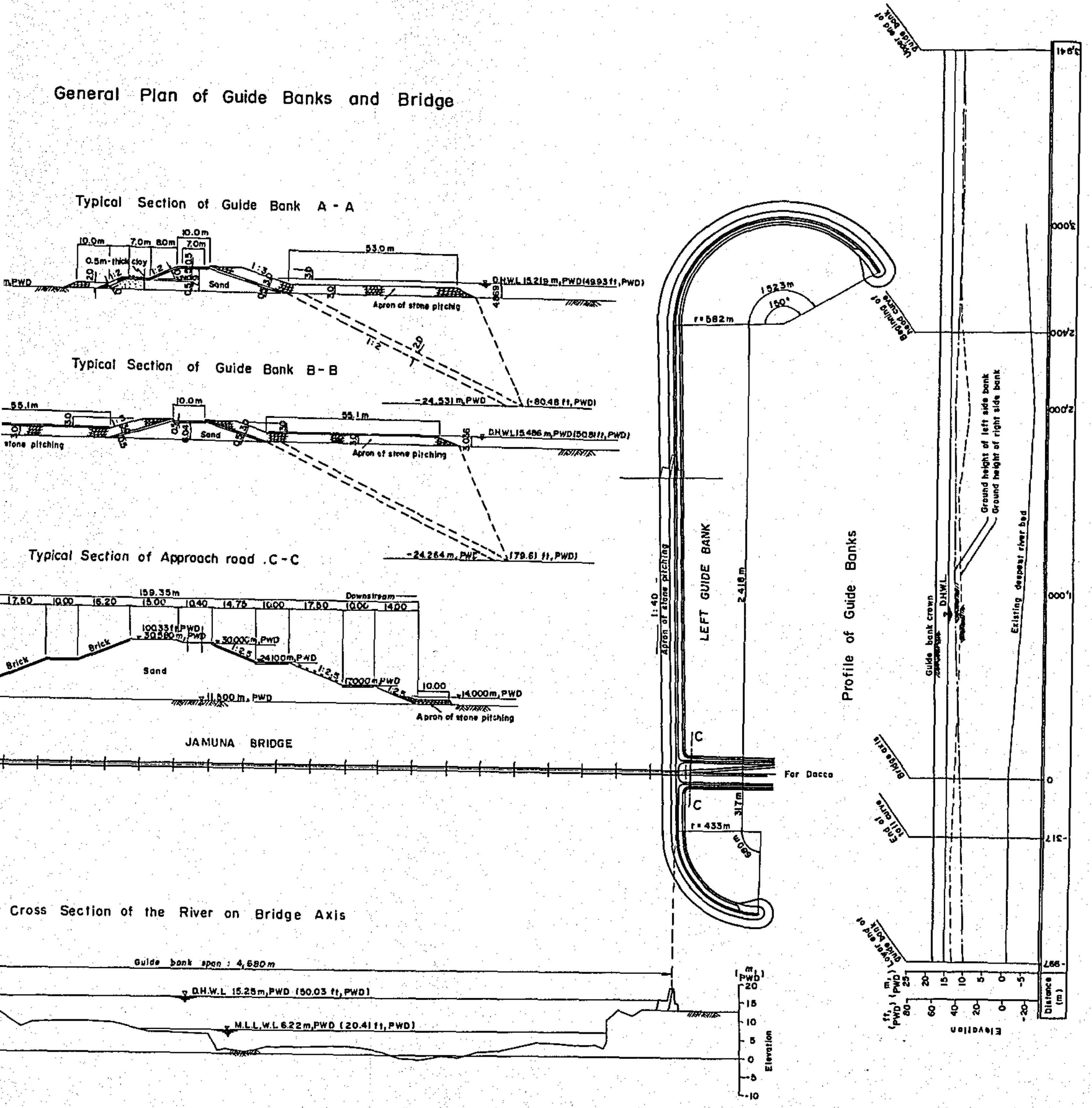


Cross dam Crossing the Dhaleswari River



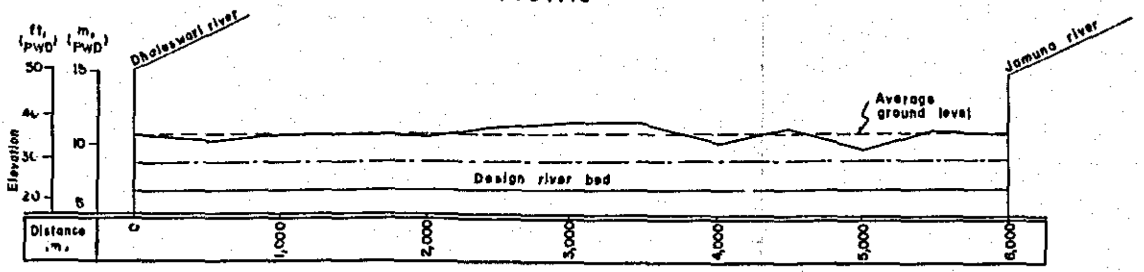


Appendix A

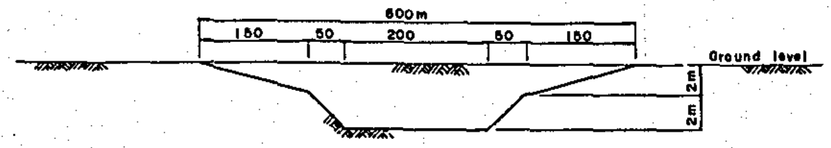


Dhaleswari New Channel

Profile

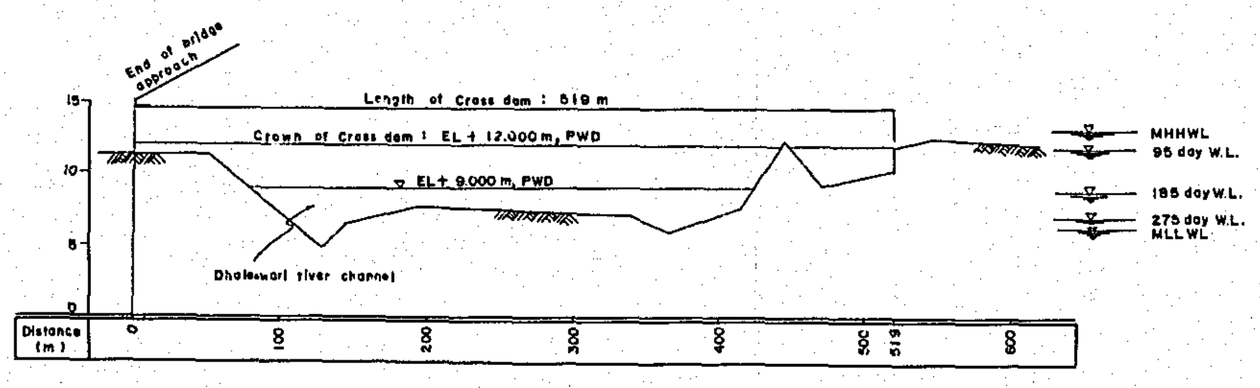


Standard Cross Section

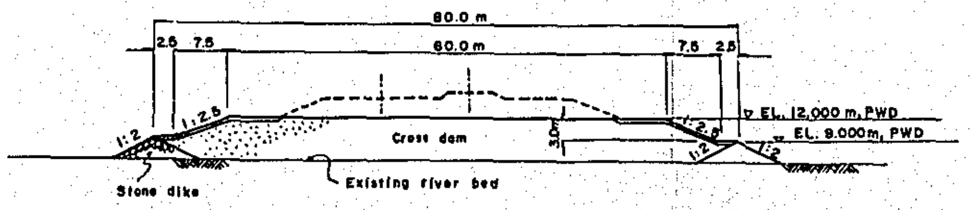


Cross dam Crossing the Dhaleswari River

Profile



Typical Cross Section of Cross dam



PEOPLES' REPUBLIC OF BANGLADESH

JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

VOLUME II RIVER CONTROL

DESIGN OF GUIDE BANKS AND DHALESWARI NEW CHANNEL

JAPAN INTERNATIONAL COOPERATION AGENCY

NIKKEN CONSULTANTS, INC.

Scale	Date
Drawn	DRW. NO. II-1
Approved	

Appendix B Equipment Schedule

Works: Guide bank

Item	Unit	Year								Total
		6th	7th	8th	9th	10th	11th	12th	13th	
EQUIPMENT (FOREIGN)										
Tractorshovel ($5m^3$)	nos		6	6	6	6				
Dump truck (32t)	"		19	19	19	19				
Tire-dozer (19t)	"		6	6	6	6				
Bull-dozer(swamp,,16t)	"		9		9					
Vibro-pile driver(15KW)	"		73		73					
Crawler crane (20t)	"		73		73					
Sheet pile (5mx0.333m)	t		1,355		1,355					
Engine dynamo (125KW)	nos		20		20					
Diezel pump dredger (4,000PS)	"		1		1					
Anchor barge (15t)	"		1		1					
Dredging pipe (ϕ710mmx5m)	"		1,000		1,000					
Flooter(ϕ1,300mmx4.5m)	"		268		268					
Joint (rubber, 1.5m)	"		266		266					
Macadam roller (10t)	"		16		16					
Asphalt sprayer(200 l)	"		7		7					
Tamper (60Kg)	"		6		6					

Works: Dhaleswari new channel

Item	Unit	Year								Total
		6th	7th	8th	9th	10th	11th	12th	13th	
EQUIPMENT (FOREIGN)										
Dump truck (32t)	nos					2	2	2		
Bull-dozer(swamp.,16t)	"					5	5	5		
Vibro-pile driver(15KW)	"					3		3		
Crawler crane (20t)	"					3	2	3		
Engine dynamo (125KW)	"					3		2		
Diezel pump dredger (4,000PS)	"					1	1	1		
Anchor barge	"					1	1	1		
Dredging pipe (ϕ710mmx5m)	"					1,000	1,000	1,000		
Flooter(ϕ310mmx4.5m)	"					268	268	268		
Joint (rubber, 1.5m)	"					266	266	266		
Sheet pile(5mx0.333m)	t					1,355	1,355	1,355		

Appendix C Labor Schedule (Max. Number of field labor per a day)

Works	Description		1st	2nd	3rd	4th	5th	6th
Guide-banks								
Apron	Skilled	Foreign labor	76	76	76	76	-	-
		Local labor	77	77	77	77	-	-
	Unskilled	Local labor	2,208	2,203	2,203	2,209	-	-
Embankment	Skilled	Foreign labor	1,218	-	1,218	-	-	-
		Local labor	167	-	167	-	-	-
	Unskilled	Local labor	5	-	5	-	-	-
Dike protection	Skilled	Foreign labor	-	-	-	-	-	-
		Local labor	625	-	625	-	-	-
	Unskilled	Local labor	796	-	796	-	-	-
Dhaleswari new channel								
Sheet pile	Skilled	Foreign labor	-	-	-	33	-	33
		Local labor	-	-	-	-	-	-
	Unskilled	Local labor	-	-	-	-	-	-
Dredging	Skilled	Foreign labor	-	-	-	79	81	79
		Local labor	-	-	-	40	40	40
	Unskilled	Local labor	-	-	-	-	-	-

APPENDIX D

BIBLIOGRAPHY AND DATA

All bibliography and data collected in Bangladesh and in Japan and used in the present study are listed in this appendix. For the convenience of reference, they have been calssified 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 firm.

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 Sources
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	"

Seri. No.	Kind of Data	Bibliography or Data	Data Source
17	DIS	HYDROLOGICAL YEAR BOOK, 1968 - 69 Vol III : Discharge	Surface Water, BWDB
18	ADM	Organization Chart of BWDB and River Morphology, Research and Training	River Morphology, Research and Training, BWDB
19	GN	REPORT ON STUDY OF BANK MOVEMENT OF RIVER BRAHMAPUTRA by IECO, 1964	"
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	"
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24	FLD	BWDB WATER SUPPLY PAPER - 308 Annual Report on Flood in East Pakistant 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	"
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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

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33	PJT,CS	Serajganj Town Protection Project ◦Plan : scale 16" = 1 mile ◦Weekly progress report for the week ending, 17 Aug. 1973	Western Zone, BWDB
34	GN	WATER RESOURCES DEVELOPMENT AND FLOOD CONTROL IN BANGLADESH	Planning, BWDB
35	PJT	BRAHMAPUTRA LEFT EMBANKMENT by International Engineering Co. Inc., 1965	"
36	PJT	BRAHMAPUTRA FLOOD EMBANKMENT PROJECT: Feasibility Report, Phulchari to Sirajganj; by International Engineering Co. Ltd., 1962	"
37	PJT	BRAHMAPUTRA FLOOD EMBANKMENT PROJECT: Definite Report by International Engineering Co., Ltd.	"
38	PJT	BRAHMAPUTRA BARRACE; Studies	"
39	PFT	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: Discharge 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	"

Seri. No.	Kind of Data	Bibliography or Data	Data Source
46	RC	Cross Section of the Brahmaputra River Within the Extent from Aricha to Bahadurabad for the Period from 1965 to 1973	River Morphology, BWDB
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	"
52	RF	HYDROLOGICAL YEAR BOOK, 1969 - 70 Vol I: Rainfall & Evaporation	"
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	"
55	WL	Water Level Record of Regular and Valley Gauges for the Period from Apr. 1970 to Mar. 1971	"
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 1960/70 and 1972/73, Apr. 1973	"
60	CS	Price Index for 1972/73; °Wholesale Prices of Agricultural Products in Bangladesh Including Detail 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	"

Seri. No.	Kind of Data	Bibliography or Data	Data Source
61	ADM	MANIFESTO OF BANGLADESH AWAMI LEAGUE	AWAMI LEAGUE IWATA
62	RC	Sounding Maps; scale 1 : 25,000 Nagarbari to Mirkutia via Char Pechokhole Sohagpur to Sirajganj Ghat, Sirajganj	
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
69	FLD	BWDB WATER SUPPLY PAPER - 119 Annual Report on Flood in Bangladesh for 1962	"
70	FLD	BWDB WATER SUPPLY PAPER - 182 Annual Report on Flood in Bangladesh for 1963	"
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73	WL	HYDROLOGICAL YEAR BOOK, 1967-68 Vol II : Water Level	"
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75	RF	BWDB WATER SUPPLY PAPER - 170 Daily Rainfall of East Pakistan Jan. to Dec., 1961	"

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78	GN	Line Diagram Showing Important River System in Bangladesh	"
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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, 1st Phase	"
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84	WL	HYDROLOGICAL YEAR BOOK, 1969 - 70 Vol II Part - A : Water Level	Surface Water, BWDB
85	CS	Unit Cost of Construction Works, Materials and Wages	Western Zone, BWDB
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87	GN	MASTER PLAN: Vol II by IECO	River Morphology, BWDB
88	PJT	REPORT FOR PRELIMINARY ENGINEERING SURVEY AND CONSTRUCTION ESTIMATE FOR ISHURDI-PABNA-NAGARBARI RAILWAY PROJECT, 1963	Railway, MOC
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91	PHT	Aerophotographs Covering the Jamuna River for 1952, 1960 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
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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 Laboratory
97	SVY	Geodesic Triangulation Station	Survey of Bangladesh
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