4.6 Traffic Benefits and Losses

4.6.1 Benefits and Losses

1) Benefits

Economic benefit of the construction of the new Krungthep Bridge or Thonburi Road Extension is defined in this study as the savings in economic cost of vehicle operation and time values to passengers and crews using the road network system between the cases of with the project and without the project. This approach of looking at the entire network rather than limiting to benefits to those accruing to users of the bridge or the road is necessary because the changes in traffic pattern induced by the project will also affect non-users of the bridge who share the same road space included in the paths of the bridge or road users.

Ordinarily the economic benefit of an urban transport investment is equated with the consumer surplus realized by the lowering of transport cost (sum of vehicle operating cost and travel time cost) as shown in Fig. 4.6.1. The reduction in travel cost is enjoyed by the existing trip makers, resulting in the total amount of benefit accrued to the existing trip makers as represented by the shaded rectangle. As the trip cost is lowered, additional trips are induced. The total amount of benefit accrued to these additional trips can be represented by the shaded triangle. When the road network is well below its capacity and unit travel cost is not affected by traffic volume, additional traffic does not change the unit cost and, therefore, does not affect the amount of benefit accrued to the existing traffic.

The situation is different where the road network is severely congested as shown in Fig. 4.6.2. The unit travel cost increases as the traffic volume increases in the range of congestion. When additional network capacity is provided, the unit travel cost of the existing traffic is lowered to the corresponding point. Additional traffic induced by the cost reduction, however, forces the unit cost to increase, reducing the amount of benefit to the existing traffic along the way. The end result could be only a small amount of total benefit.

In this Study traffic between any origin and destination was assigned onto the network only when there is still a reasonable route with excess capacity as described in Section 4.5. The amount of traffic which could not be assigned was explicitly calculated as the suppressed demand. When the assignment is repeated with the improved network, the amount of induced additional traffic can be obtained as the difference in the suppressed demand.

Benefit calculations in this Study were done taking the assignment results including the induced (or released) additional traffic. The amount of benefit immediately after the opening of the bridge could be higher since a higher amount of unit cost reduction to all existing traffic under little additional traffic may result in a higher total benefit. Such situation, however, would be short lived where additional traffic comes from those hitherto suppressed, rather than from those generated. Therefore, the amount of benefit to existing traffic before

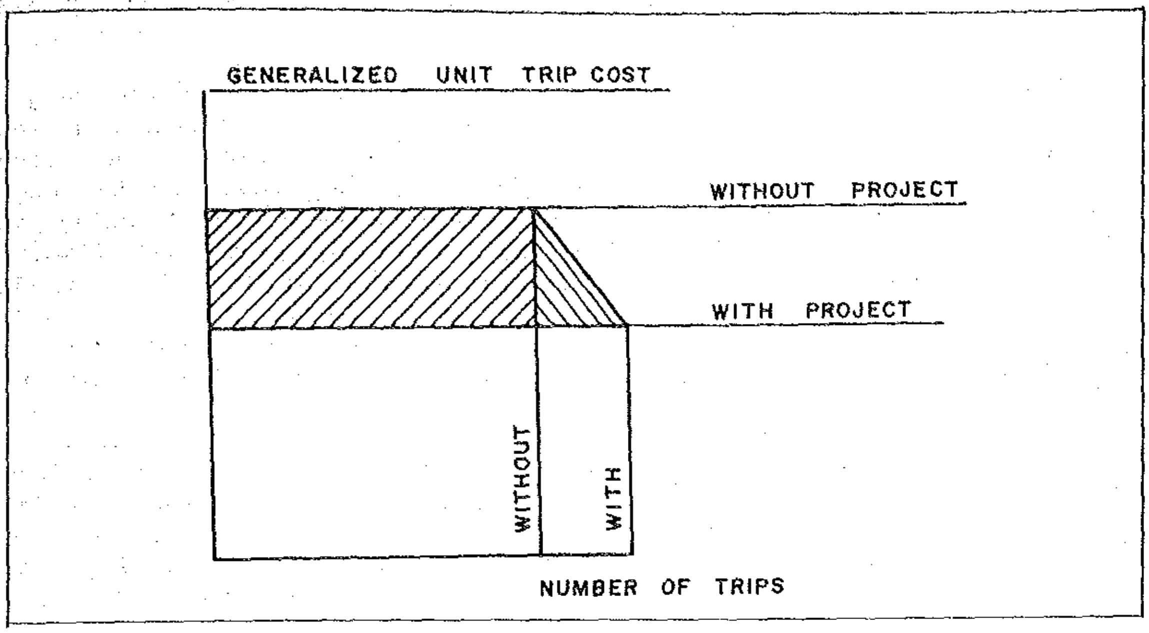


Fig. 4.6.1 Benefits Under No Congestion

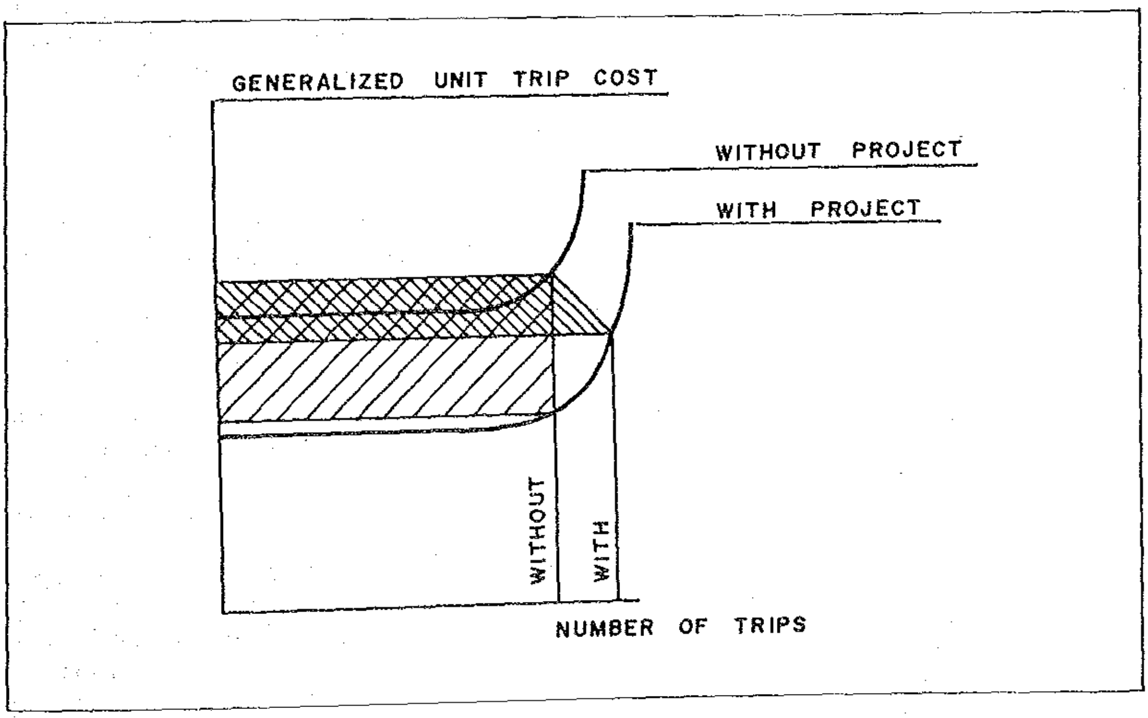


Fig. 4.6.2 Benefits Under Congestion

the additional traffic induced was ignored in this Study, making its benefit estimates conservative.

Traffic assignments were carried out for each of the three target years of 1991, 2001 and 2011 with the combination of origin and destination matrix and the network corresponding to various alternative cases including the do-nothing case, the low bridge case and the high bridge case. As far as the intersection delay or link delay is concerned, the high bridge type and the low bridge type with flyover intersections are almost identical provided that the effect of the grade of the high bridge be ignored. The first stage of the staged construction of the low bridge type, however, includes no flyovers or one limited to a single movement and is not much different from the existing situation in terms of intersection delays. For each of "loaded" links average speed and travel time including waiting time were calculated and vehicle operating cost and time cost were calculated to be summed into the network-wide total generalized total costs, which were then divided by corresponding total number of trips which could be assigned to yield unit travel costs by case. The comparison between the do-nothing case and each of the alternative cases produced the total amount of benefit.

The process described in the foregoing paragraph was repeated for the morning peak period, the evening peak period, and the off-peak period. It turned out that the difference in the total benefits of the morning peak period and the evening peak period did not differ much. Therefore, results for the morning peak period were taken to represent all peak hours. Five times of the total hourly benefit for the morning peak and 15 times of the total hourly benefit for the off-peak were added to give the total daily benefit amount.

2) Losses

Economic loss due to the closure of the Krungthep bridge, for a period of time during construction, was estimated by comparing the total economic travel costs of cases with or without the bridge.

4.6.2 Vehicle Operating Costs

In a recently completed report - Special Report on Review of the Previous Study, Detailed Design and Environmental Impact Assessment of the Second Stage Expressway in Greater Bangkok, May 1986 - vehicle operating costs were developed for eight vehicle types at various speed levels, from 5 kph to 90 kph. Vehicle types for which operating costs were estimated are: cars, motorcycles, taxis, medium buses, pikups, heavy buses, medium trucks and heavy trucks. JICA;s Feasibility Study on the Second Stage Expressway System in the Greater Bangkok, 1983, and STTR's Internal Working Paper No. 6, Travel Costs, were the primary information sources. The former was particularly valuable in that it utilized the results of actual fuel consumption surveys in urban conditions in Japan, where vehicle types ad traffic conditions are similar to those in Bangkok. Price levels in May 1986 were used to update the component prices and subsequently the operating costs. Details are shown in Appendix 4.6.1.

Table 4.6.1 Traffic Composition Projections

	Morning Peak				Evening Peak				Off-Peak			
	1986	1991	2001	2011	1986	1991	2001	2011	1986	1991	2001	2011
Motorcycles	26.9	28.6	26.3	21.1	24.6	26.2	24.1	19.3	24.5	25.8	26.7	21.3
Cars	45.0	43.5	46.3	50.4	43.0	41.6	44.2	47.9	34.6	33.5	34.5	37.2
Taxis	13.1	13.3	13.0	14.2	14.1	14.4	14.0	15.2	17.6	17.9	16.9	18.2
Pickups	8.6	8.8	9.5	10.3	11.3	11.6	12.4	13.4	15.3	15.7	16.3	17.6
Heavy Trucks	0.7	0.6	0.5	0.4	0.9	0.8	0.7	0.6	2.5	2.2	1.5	1.2
Buses	5.8	5.2	4.5	3.6	6.1	5.4	4.6	3.6	5.4	4.8	4.0	3.1

Source: Computed by the Study Team from counts by JICA BMA Study

Note: 1. Percentages do not add due to rounding.
2. 6-wheel and 10-wheel trucks were assumed 55% and 45% of Heavy Trucks respectively.

Table 4.6.2 Vehicle Operating Costs

Speed kph	Car	M/C	Taxi	Med.Bus	Pickup	Hev.Bus	Med.Truck	Hev.Truck	PCU Morning Peak	PCU Evening Peak	PCU Off-Peak
5	3459	860	2453	4611	2518	10505	5645	7363	3447	3399	3268
10	3095	791	2167	3778	2252	8374	4608	5968	3025	2978	2856
15	2721	685	1910	3226	1938	7076	4045	5221	2636	2594	2487
20	2471	617	1762	2885	1753	6327	3704	4774	2390	2352	2257
25	2282	568	1656	2654	1621	5834	3512	4521	2212	2177	2092
30	2142	522	1585	2479	1525	5482	3350	4310	2078	2047	1969
35	2040	513	1541	2375	1473	5261	3259	4188	1994	1965	1894
40	1955	495	1505	2288	1433	5090	3186	4092	1922	1895	1829
45	1892	482	1481	2243	1404	4988	3166	4071	1871	1845	1785
50	1849	476	1475	2210	1390	4906	3139	4035	1838	1814	1758
55	1811	470	1468	2210	1374	4905	3136	4030	1813	1790	1737
60	1814	465	1468	2210	1364	4910	3141	4039	1813	1789	1735
65	1824	468	1474	2248	1354	4919	3175	4085	1821	1796	1742
70	1827	468	1474	2305	1362	5050	3211	4136	1831	1807	1753
75	1840	472	1487	2369	1372	5145	3283	4235	1849	1825	1771
80	1859	480	1505	2477	1392	5291	3405	4398	1877	1854	1800

For the purpose of economic evaluation average vehicle operating cost per passenger car unit was developed by taking weighted average of vehicle operating costs by vehicle type with associated overall traffic composition percentages as shown in Table 4.6.1. Taking the significant difference in composition by time of day into account three sets of traffic composition percentages were applied to obtain average vehicle operating costs for morning peak period, evening peak period and off peak period. Results are shown in Table 4.6.2.

4.6.3 Time Values

Time value of passengers and crews using the road network by each vehicle type developed by the aforementioned Special Report were examined and adopted in this study. Details are shown in Appendix 4.6.2. Values for future years were increased to reflect increase in per capita income in real terms. Table 4.6.3 summarizes the resulting values of time for each vehicle type and for each target years. Time value per passenger car unit was developed in a manner similar to VOC per PCU and are also shown in Table 4.6.3.

Table 4.6.3 Passenger and Crew Time Values

(in Baht per vehicle hour at 1986 prices)

Vehicle Type	1986	1991	2001	2011
Motorcycle	7.6	8.7	11.7	15.7
Car	18.6	21.2	28.6	38.5
Taxi	35.5	40.5	54.7	73.5
Pickup	34.4	39.2	53.0	71.2
Truck	27.3	31.1	42.0	56.5
Bus	259	296	399	537
PCU (morning peak)	56.7	61.8	75.6	90.5
(evening peak)	58.1	62.9	76.6	91.2
(off peak)	55.2	59.9	74.4	89.8

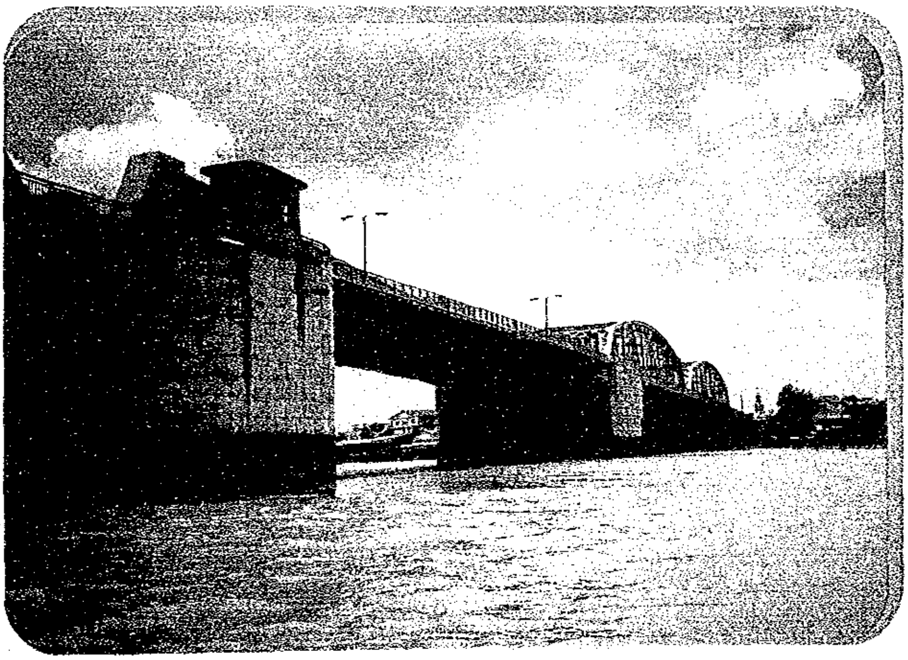
Source: Special Report SES Detailed Design and Study Team

4.6.4 Development Benefit

In the case of the Thonburi Road Extension, induced population increase was estimated, which resulted in higher traffic demand estimates for directly affected zones. Therefore, development benefits can be quantified in the form of a higher road user benefit.

No development benefit, however, was taken into account for the construction of the New Krungthep Bridge.

PART III
NEW KRUNGTHEP BRIDGE



CHAPTER 5

NECESSITY OF NEW KRUNGTHEP BRIDGE

5.1 Evaluation of the Existing Krungthep Bridge

The geographical location of the existing "Krungthep Bridge is at 13°40'55" North Latitude and 100°31'05" East Longitude.

This existing bridge is a 450.3-meter long bridge crossing over the Chao Phraya River, and connecting Sathu Pradit District in Bangkok side and Rat Burana District in Thonburi side. It hs a 60.0 meter bascule span in its center to allow ships passing on the river.

The bridge, which has a 11.5-meter wide carriageway and 2.5 meter sidewalks, is used as a 4-lane highway bridge.

As rapid increase in traffic volume on the bridge is expected, enlargement of traffic capacity of the bridge is desired.

The Study Team conducted an evaluation of the structural soundness the existing bridge in order to determine the possibility of the enlargement of traffic capacity. A similar evaluation of the bridge was made by JICA from 1981 to 1982. Afterwards, PWD executed the rehabilitation work of the bridge in 1984.

Therefore, the present strengthened state of the bridge after the rehabilitation, as shown in Fig. 5.1.1 was taken into consideration in this study.

5.2 History of the Existing Bridge

The Study Team interviewed Dr. Charoon Rojwithya, Road and Bridge Section, Construction Division of PWD, about the history of the existing bridge. The history of the bridge as known through the interview is summarized in chronological order below.

<u>August 1954 to June 1959</u>

The existing Krungthep Bridge was constructed to facilitate vehicle transport over the Chao Phraya River between Bangkok and Thonburi districts.

Details of the construction were as follows:

- Construction Cost : ฿31.9 million
- Total Bridge Length : 450.3 m
- Composition of Carriageway & Sidewalk : carriageway = 12.0 m (4 lanes)
sidewalk = 2 @ 2.5 m

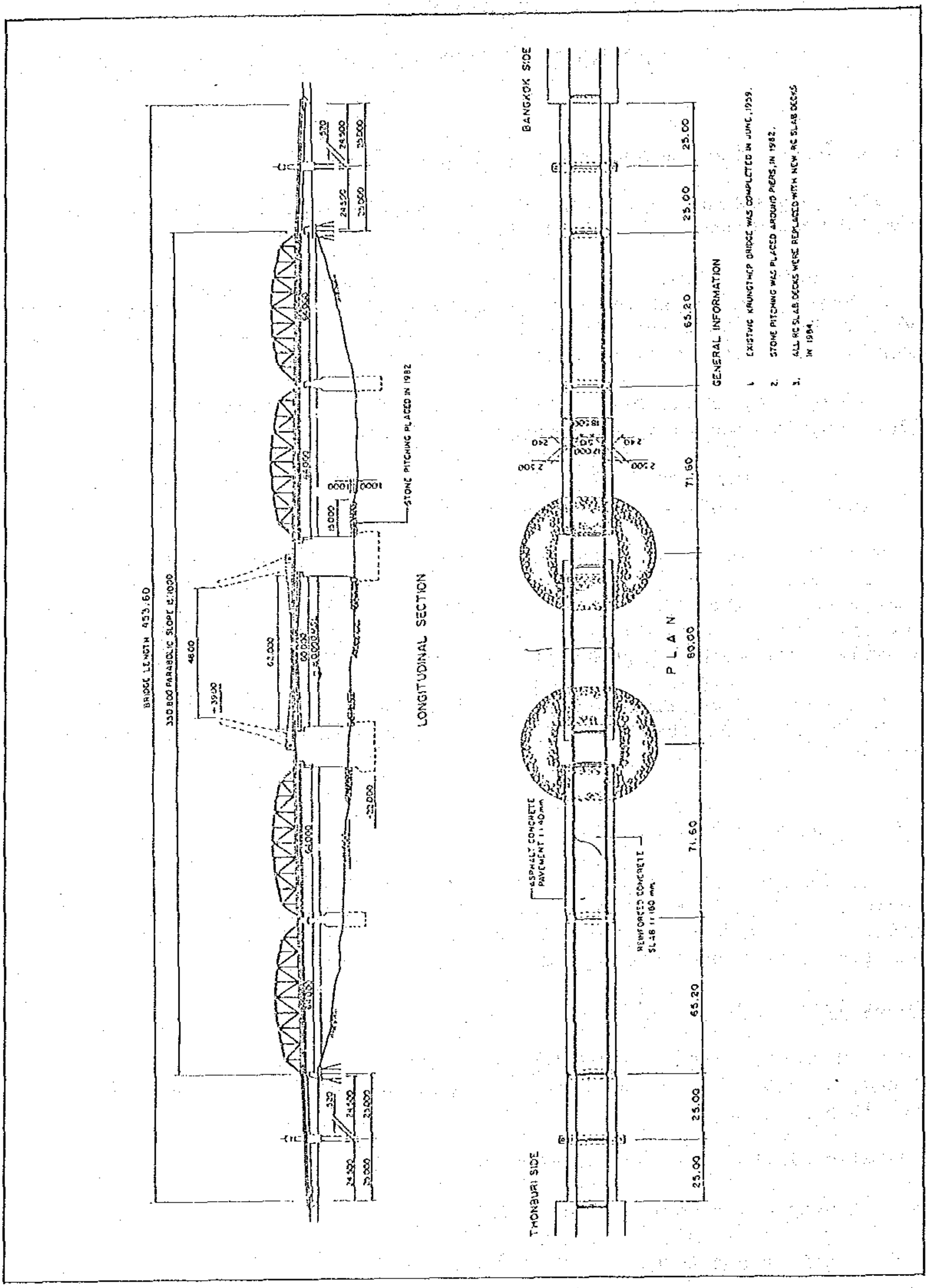


Fig. 5.1.1 General View of Existing Krungthep Bridge

- Vertical Clearance	:	7.5 m above MSL
- Superstructure	:	4 nos of 24.5 m long PC composite beams (I-Section) 4 nos of 64.0 m long steel truss girders 1 no of 60.0 m long (clear span) steel bascule bridge
- Substructure	:	2 nos of oval type open caisson piers (Supporting bascule bridge) 4 nos of wall type piers with concrete piles (Supporting PC composite beams) 2 nos of stub abutments with concrete piles (Supporting PC composite beams)
- Approach Road	:	Bangkok side = 180.55 m Thonburi side = 127.7 m

October 1979

PWD appointed a Thai Consultants - Sri Sathaporn Ltd. - for the bathymetric survey of all bridge sites along the Chao Phraya River in order to clarify the riverbed profile. From the results of the survey, scour around open caissons supporting the bascule bridge was observed.

1981 to 1982

According to the survey results in 1979, PWD took a countermeasure to protect pier foundations against scour by placing stone pitching around the caissons.

1981 to March 1982

In parallel with stone pitching works by PWD, JICA carried out technical studies on strengthening and rehabilitating the Krungthep and Krungthon bridges which had been suffering from serious deterioration by rapid increase in traffic volume and in vehicle weight.

In that study, the JICA study team recommended PWD to carry out repair work for the deteriorated elements such as RC slab deck, steel truss members damaged by cars, and others.

January 1984 to October 1984

PWD prepared detailed drawings for rehabilitation of the superstructure based on the JICA recommendations, then completed the rehabilitation work in 1984.

Major items of the work were as follows:

- Replacement of the RC decks with:
  - 16 cm thick slab for steel truss girders

• 18 cm thick slab for PC composite beams

However, the thickness of decks on the steel bascule bridge was not increased.

- Change of carriageway width by provision of new kerbs:
  - Steel truss girder : 11.5 m
  - Steel bascule girder : 12.65 m (without kerbs)
  - PC composite beam : 11.5 m

- Repair of corroded steel members

- Repair of damaged members by cars

The total cost of the rehabilitation works was ฿ 14.4 million.

5.3 Site Surveys

Site surveys were conducted on the existing Krungthep Bridge in May, 1986 to obtain data necessary to supplement the previous study prepared by JICA in March 1982.

At first, visual inspection was carried out for both superstructure and substructure. Subsequently, the following field tests were completed.

5.3.1 Compressive Strength Test of Concrete

Schmidt Hammer test was made on the existing concrete surface of PC composition beams and piers in order to estimate their compressive strength.

The testing procedure followed the "Guidelines for Schmidt Hammer Test adopted by Japan Society of Architects".

The test results are shown in Appendix 5.3.1.

As result, the compressive strength and allowable stress, to be applied in the structural evaluation in the Study were obtained as shown in Table 5.3.1.

Table 5.3.1 Summary of Schmidt Hammer Test

Unit: Kgf/cm

	Compressive Strength	Allowable Stress
PC Composite Beam	405	135
Pier	295	95

5.3.2 Alkalinity Test

It is well known that the alkalinity inherent in concrete becomes neutralized gradually year by year. In order to clarify the depth to which the concrete quality had already neutralized, alkalinity test was carried out by using 1% phenolphthalein solution.

The test results are shown in Appendix 5.3.2 and the maximum depths neutralized are as summarized in Table 5.3.2.

Table 5.3.2 Summary of Alkalinity Test

	Max. Depth Neutralized
PC Composite Beam	1.0 cm from concrete surface
RC Pier	1.8 cm from concrete surface

5.4 Structural Evaluation

As mentioned in the preceding Section 5.2, stone pitching was placed around piers in 1982 to protect foundations of piers against scour, and the rehabilitation of superstructure was completed in 1984.

The Study Team carried out a structural evaluation of the present Krungthep Bridge taking into consideration the abovementioned engineering evidence obtained through the past reinforcing works.

5.4.1 Loading Applicable to the Evaluation

1) Dead Load

The thickness of RC slab deck was increased during the rehabilitation work in 1984, from 12 cm to 16 cm and from 16 cm to 18 cm, for steel truss girder and for PC composite beam, respectively.

The increased dead weight was calculated for structural analysis and the induced stressess were incorporated to those in the previous JICA study report of March 1982.

2) Live Load, Impact and Sidewalk Load

The existing Krungthep Bridge was originally designed on the basis of 29.25 ton Tractor - Truck loading stipulated in the Specifications of the Government of the Kingdom of Thailand. Live load intensity of 29.25 ton Tractor - Truck loading is nearly equivalent to that of HS-15 and TL-16 in AASHTO (the American Association of State Highway and Transportation Officials) and JRA (the Japan Road Association) standards, respectively.

On the other hand, the bridges planned for the Middle Ring Road are, at present, to be designed based on HB-45 unit load in BSI (British Standards Institution) which is established for the 120-year probability loading in UK. From the results obtained in the previous study report by JICA, it is obvious that the existing Krungthep Bridge has quite a substandard superstructure to bear such a heavy vehicle load as HB-45 unit.

From the traffic survey made in April to May 1986 it appears that the vehicle models passing over the existing Krungthep Bridge in Thailand are very similar to those in Japan at present.

In this respect, the Study Team considers it necessary to take into consideration not only HB-45 unit in BSI, but also TL-20 and HS-20 prevailing in bridge design in Japan and USA at present, respectively, in the succeeding structural analysis.

The live load, impact and sidewalk load considered in this study are as follows:

<u>BSI Standards</u>

- Live Load : (HB-45 units & HA oad) x 1.1 1/
- Impact Fraction : included in live load
- Sidewalk Loading: 3,485 Pa (0.355 $t.f/m^2$) 2/... Truss Gr (L=64m)
  4,715 Pa (0.480 $t.f/m^2$) ... Bascule (L=34mx2)
  5,000 Pa (0.510 $t.f/m^2$) ... PC T-Beam (L-24.5m)

<u>JRA Standards</u>

- Live Load : TL - 20
- Impact Fraction : $i = \frac{20}{50 + L}$ .... Steel Gr

  $i = \frac{20}{50 + L}$ .... PC T-Beam (for T-Load)

  $i = \frac{20}{50 + L}$ .... PC T-Beam (for L-Load)
- Sidewalk Loading: 3.430 Pa (0.350 $t.f/m^2$) .... All Bridges

<u>AASHTO Standards</u>

- Live Load : HS - 20
- Impact Fraction : $i = \frac{15.24}{L + 38}$ .... For all bridges (Max. = 30%)

1/ : As Structural analysis is made based on the service load design method, the live load HB-45 and HA are multiplied by 1.1 for Loading Combination - 1 in BSI.

2/ : Unit = SI unit (Metric unit)

- Sidewalk Loading: 1,980 Pa (0.202 t.f/m^2) .... Truss Gr (L=64m)
  2,544 Pa (0.259 t.f/m^2) .... Bascule (L=34mx2)
  2,873 Pa (0.293 t.f/m^2) .... PC T-Beam (L-24.5m)

3) Forces Considered Substructure Evaluation

In addition to the above (i) and (ii), the following forces were taken into consideration in the evaluation of piers.

- Stream Current Force:

  P =515 K.V ..... based on AASHTO Standards

  where
  P : pressure by stream current (Pa)
  V : water velocity (m/s), being 2.0 m/s
  K : a constant, being 2/3 for circular piers (open caisson)

- Buoyancy

- Earthquake Force

  EQ = 0.05 W

  where
  EQ : horizontal force applied at the center of gravity of the structure (tf)
  W : dead weight of the structure (tf)

5.4.2 Superstructure

1) Stresses by Respective Live Loads

The existing bridge is composed of steel truss girders, steel bascule girders, and PC composite beams. Stresses in the respective girders or beams were calculated based on the service load design method, so called allowable stress design method, for the three different live loads as specified in BSI, JRA and AASHTO.

The details of this calculation are shown in Appendix 5.4.1 and the results are summarized below:

a) Steel Truss Girder

The total stresses, caused by the existing dead weight and HB-45 unit live load (BSI), were estimated to be over their allowable limits in all members of steel truss girders.

For example, the excessive stress of main chord was estimated at 23% of its allowable limits, and those of stringer and diaphragm were 75% and 30% respectively.

However, the live loads to TL-20 (JRA) and HS-20 (AASHTO) were judged acceptable to all the members of the existing truss girders.

b) Steel Bascule Girder

As same as in case of steel girders, the total stresses caused by the existing dead weight and HB-45 unit live load were estimated to be larger than allowable stresses in all members. Such excessive stresses were 48% of the allowable limits in the main girder, 45% in the stringer and 32% in the diaphragm.

However, in case of the TL-20 or HS-20 live load, the total stresses were estimated to be within the allowable in any of the members.

c) PC Composite Beam

The total fiber stresses of the main beams, caused by the existing dead weight and HB-45 unit load, exceed the allowable stresses both in the tension and compression sides, while those by TL-20 or HS-20 live load were within the allowable stresses.

2) Residual Life of Superstructure Affected by Natural Conditions

Residual life of structure is affected not only by live load but also by natural conditions.

As the structural studies related to live load has been already discussed in the preceding Section (1), the residual life as affected by natural conditions given the construction materials used in Thailand, is examined hereinafter. However, the residual life of a steel bridge cannot be analyzed in precise quantitative terms, because it depends much upon the anti-corrosive painting work in the future.

In this respect, only the residual life of concrete, PC composite beams, is studied hereunder.

The estimation of residual life of concrete in PC composite beams was made by adopting the following relationship:

$$t = \frac{k}{R^2} \cdot X^2$$ 1/

where, t : time expended on the concrete neutralization (Year)
k : constant, being calculated as: 0.3 (1.15+3w)/(w-0.5)
w : water cement ratio
R : constant related to the concrete materials
X : depth of concrete neutralized (cm)

It should be noted that the constants in the above equation were determined based on the severe natural conditions and construction materials produced in Japan.

1/ : Report "Neutralization of Concrete Affects Corrosion of Reinforcing Bar" by Minol HAMADA Cement Concrete, No. 272, 1969.

In order to adopt the appropriate constants in Thailand, the Study Team extracted the data obtained in the field test by phenolphthalein as mentioned in Section 5.3 of this chapter, and the fraction of k/R obtained was as follows:

$$\frac{k}{R^2} = 86.5$$

Hence, the residual life of concrete, which is affected by natural conditions, is estimated to be:

$$T = \frac{k}{R^2} (D^2 - d^2) = 86.5 \ (3^2 - 1^2) = 690 \text{ years}$$

where, T : residual life of concrete (year)
D : concrete cover (cm) = 3 cm
d : max. neutralized depth of concrete at the field survey (cm) = 1 cm

Therefore, no problem is anticipated as far as the neutralization of concrete quality in superstructure is concerned.

3) Present Conditions of Center-Lock-Key of Steel Bascule Girder

As discussed in Section 5.2, the rehabilitation of the existing bridge was completed in October 1984. However, a large amount of maintenance work has been carried out continuously by the staff of the PWD maintenance office for the center part of the bascule girder, i.e. the center-lock-key and expansion joint of the present bridge. Distorted bushes in the center-lock-key have been replaced every 6 months, and expansion joints which are made up of several mechanical components have been repaired every 3 months or so.

The present bascule girders are considered to have the following problems:

- As the stringers at the center of bascule girders are not longitudinally continuous, the deflection of bridge decks on loaded span differs from that on unloaded span. Such a different deflection is estimated at 14 mm for the live load TL-20, which may cause serious vibration of bridge decks during passing of vehicles.

- Thermal movement of bascule girders may cause a significant shear stress in the center-lock-key which follows the damage of bushes when the center-lock-key does not have a sufficient longitudinal clearance to allow for the thermal movement.

4) Superstructure Evaluation

As a result of the above study, the following was concluded:

- All the superstructures, i.e. steel truss girders, steel bascule bridge and PC composite beams, have insufficient capacities to carry such a heavy live load as HB-45 unit in BSI.

- As for the live loads of TL-20 specified in JRA and HS-20 in AASHTO, either of TL-20 or HS-20 is applicable to steel truss girders ad PC composite beams.

- As far as the neutralization of concrete quality in superstructure is concerned, no problem is anticipated.

5.4.3 Substructure

1) Stability of Piers for Steel Bascule Bridge

Stability calculation was made for the piers for steel bascule bridge using the following assumptions which were adopted in the similar projects along the Chao Phraya River.

- Formula for estimating scour depth:
  (Source: Detailed Design of Rama VI Bridge)

  DS = 0.6 x B x 2
  where, Ds : scour depth (m)
  B : width of the pier (m)

- Water velocity for estimating stream current force:
  (Source: Detailed Design of Rama VI Bridge)

  V = 2.0 m/s

- Subsoil condition:
  (Source: Detailed Design of Watsai Bridge, Final Report)

  N-Value of SPT = 20 to 30, at the depth of - 22.0 m from
  (at bearing strata) MSL (foundation elevation of caisson)

- Riverbed Elevation: -17.0 m from MSL
  (Source: Report of Bangkok Bridge Survey)

The type of foundation is actually open caisson, but the fraction of (Df: rooting depth of foundation) / (B: foundation width) is 5/13. According to the article 5.2 of the Specifications for Substructure Design of JRA standards, the structural system of caisson shall be taken as spread footing for stability analysis in case that the fraction of Df/B is less than 1/2.

Therefore, the calculation was made as spread footing and the results are summarized in Table 5.4.1.

2) Residual Life of Substructure Affected by Natural Condition

The same procedure as in the preceding Section 5.4.2 was applied in determining the residual life of the substructure as far as the neutralization of concrete quality is concerned. It was found that the substructure has a sufficient length of residual life as well.

Table 5.4.1 Summary of Stability of Pier

		Normal Time	Earthquake (K = 0.05)
Overturning	e	0.97 m*	1.86 m
	ea	2.07 m	4.13 m
Sliding	H	0 tf	438 tf
	Ha	420 tf	470 tf
Ground Reaction	V	4,380 tf	3,984 tf
	Va	4.600 tf	4,200 tf

Note: * ..... In case that the bascule bridge is drawn up.

3) Substructure Evaluation

As a result of the above study, the following were concluded:

The stability of bascule piers was confirmed on the condition that no scour would occur to the depth of -22.0 m MSL on which the caisson was founded.

As far as the neutralization of concrete quality in superstructure and substructure is concerned, no problem is anticipated.

5.5 Strengthening Possibility

It is confirmed, from the preceding subsection 5.4 that the existing bridge can bear either the live load of HS-20 or TL-20.

Strengthening of the existing bridge to withstand the live load of BSI HB-45 unit is discussed below:

1) Steel Truss Girder

The existing slab deck is of 16 cm thick RC slab type. The dead weigh of slab deck can be reduced by use of a orthotropic steel deck plate instead of the existing RC slab.

The total stresses caused by the existing dead weight and HB-45 unit live load in the upper and lower flanges of the main girders were estimated at 23%, which exceed their allowable limits. Such over stresses can be mitigated by replacing the existing RC slab with the orthotropic steel deck plate to reduce the deck weight. In this case, the closed rib type (or so called through type) of orthotropic steel deck is deemed appropriate to increase the bearing capacity and structural rigidity against the heavy live load of HB-45 unit.

As for the floor system consisting of stringers and sway bracings, the existing members can be replaced by new members which are designed against HB-45 unit load. These new members can be connected to the existing lower chords of the main girders by using high tensile strength bolts. In this strengthening work, indiscriminate field welding has to be avoided because of the original quality of the existing steel materials, which is thought unreliable for welding use. In short, the existing truss girders are judged possible to be strengthened.

2) PC Composite Beam

As the total stresses by the existing dead weight and HB-45 unit load exceed the allowable stresses both in the tension and compression sides, no appropriate strengthening method is recommended.

Therefore, new prestressed concrete composite beams, of which sections are to be so designed as to bear HB-45 unit load, are judged necessary to be constructed instead of the existing prestressed beams.

3) Bascule Bridge

The total stresses of main girders, induced by the existing dead weight and HB-45 unit live load, were estimated to exceed the allowable stresses by 21% and 48% in the top flange and bottom flange, respectively.

The existing slab deck is made of steel deck and the reduction of dead weight like in case of truss girder as mentioned in subparagraph 1), cannot be expected.

Further, the increase in dead weight is inevitable due to the stress requirements of slab decks, stringers and diaphragms against HB-45 unit load.

If the existing bridge is strengthening to withstand the live load HB-45 unit, some additional plates, about 20 m in length, are required to be fixed both on the top and bottom flanges of main girders.

The existing steel materials, produced in the 1950s, are generally thought unreliable for welding use. No field welding can be applied to strengthen the tension stress of the existing main girders especially in the flanges, lest the original quality of the existing steel should degenerate to a point of fatique failure. In case of strengthening the existing main girders by means of high tensile strength friction bolts, tightening work is judged practically impossible owing to the insufficient working space between two web plates of the existing main girders.

From the above, the strengthening method for bascule girders, as long as the bridge is used as a movable one, is judged practically impossible.

However, if the existing bascule girders are to be fixed permanently, the bending moment will be substantially mitigated and the existing main girders can be used with only minor additional work. Envisaged additional work consists in i) changing the girder center from hinge to rigid system by installing connection members, ii) increasing the counter weight by adding cast-in-place concrete, and iii) strengthening the floor system by installing additional stringers and diaphragms.

4) Strengthening Plan

From the above discussion, the following plan is recommendable in order to withstand HB-45 unit load.

a. Members of the steel truss girder can be strengthened with additional 2,100 tons of steel, which are mainly to be used for replacing RC slabs by orthotropic steel decks and stringers and cross beams.

b. Bascule girders cannot be strengthened unless they are permanently fixed. If they are to be permanently fixed, the center-lock-key can be strengthened by adding truss frames at both sides, in the same way as applied for the Memorial bridge. Counter weights will have to be attached in the operation chamber. Additional steel members of about 120 tons and concrete of about 35 cubic meters will be required.

c. The approach PC girder bridges will have to be reconstructed.

5.6 Future Utilization of the Existing Bridge

The evaluation of the existing Krungthep bridge was already discussed in the preceding Section 5.5 as summarized below:

- The carriageway width is 12.0 m being used as a 4-lane bridge;
- The center-lock-key of bascule girders is a weak point requiring PWD to carry out repair work which will cause interuption of the traffic on the bridge for a few days every year;
- The structural strength of the existing bridge is not enough to bear the live load specified in HB-45 units and HA load which are standard loads for bridges in Thailand. However, it is enough for the live loads of TL-20 or HS-20.

According to the above understanding from the structural view point, it is possible to utilize the existing bridge for two (2) or three (3) lanes with due consideration of vehicle load control.

5.7 Necessity of a New Krungthep Bridge

For expansion of traffic capacity at the existing Krungthep Bridge, it is concluded that the construction of a New Krungthep Bridge is fundamentally necessary. The scale and type of a new bridge is discussed in Chapter 8 hereinafter.

CHAPTER 6

NAVIGATION REQUIREMENTS FOR THE BRIDGE

6.1 Introduction

In Bangkok, where river banks are only one or two meters above the water surface, the distance between the river water surface and the bottom of the bridge superstructure is determined by the navigational vertical clearance. Thus the determination of navigational clearance is a crucial factor as the construction cost is very much dependent on the height of the bridge. Preliminary calculations shown in Section 8.4 indicate that the difference in construction costs between bridges with navigation clearance of 7.5 m and 34 m is more than 75% or 280 million Baht in the case of a 4-lane bridge.

The existing Krungthep Bridge is of bascule type and therefore does not put constraints on the height of passing ships. The opening of the bridge is done once or twice a day at 6 am or 9 am or 3 pm by the staff of the PWD maintenance office located at the foot of the bridge in Bangkok side upon request made by ship operators during the office hours of the preceding day. The operation is free of charge to ship operators.

Although the number of opening has been reduced from four to two times or once a day, the operation is still almost daily. In the following sections are examined various ship movements, possible restrictions on them and their implications.

6.2 Historical Background

Bridges over the Chao Phraya River have been constructed one after the other after the World War II except the old Memorial Bridge. Table 6.2.1 lists the bridges in the descending order from the upstreammost ones.

The problem of possible conflict with ship movements similar to this project arose in several occasions. The most recent case, the construction of the Wat Sai Bridge by ETA, resorted to setting the clearance at 41 m above the maximum mast height. The clearance of 41 m was given by the Harbour Department as the necessary height for the tallest ships found in their pilotage records. The Port Authority of Thailand demanded that the water area under Wat Sai be sufficient for large freighters to turn around. Their demand was eventually approved by an inter-agency committee which met five times in 1983.

When it was decided to construct the New Momorial Bridge, the Navy Shipyard located upstream of the bridge was moved to a site at the river mouth. The bascule portion of the old Memorial Bridge was permanently closed and the New Memorial Bridge was constructed with a clearance of 5.3 m above the High Water Level (HWL).

Table 6.2.1 Bridges Over Chao Phraya River

	Bridge	Number of Lanes	Year of Opening	Clearance (m) (from HWL)	
1.	Pathumthani	2	1984	5.8	
2.	Nonthaburi	2	1955	5.5	
3.	New Nonthaburi	4	1985	5.4	
4.	Rama VI	2	1951	7.6	
5.	Krung Thon	4	1955	5.5	
6.	Phra Pin Klao	6	1973	9.0	
7.	Memorial	4	1932	5.5	(Original Bascule)
8.	New Memorial	6	1984	5.3	
9.	Sathorn	6	1982	10.0	
10.	Krung Thep	4	1955	5.5	(Bascule)
11.	Wat Sai	6	1987	41.0	(Under Construction)
12.	New Rama VI	6	1991	5.5	(Plan)

There were a mooring area and a ship repair yard upstream of the Sathorn Bridge along with minor shipping facilities. The mooring area was closed and at the site of the ship repair yard now stands the Shangrila Hotel. The decision was made by PWD following recommendations made by a committee headed by a Chulalongkorn University faculty member.

The number of ships using this part of waterway has been declining primarily due to the losing competition with trucks, not much due to the above mentioned waterway closures. The Harbour Department's policy of discouraging shipping activities in this part of the river on environmental grounds has helped this tendency. Any loading/unloading operation of ships of more than 500 gross tons is required to obtain an official permit from the Department and none has been issued in recent years.

The cold storage near the Sathorn Bridge had often been supplied by large fishing boats. When another cold storage was opened at Pak Nam in Samut Prakarn, however, movements of fishing boats have largely been reduced.

The maintenance office at the Krungthep Bridge has been keeping records of passing ships. Because of the fact that multiple ship passings are often recorded only with the name of the first ship alone, their records show figures lower than actual ones, probably in the order of 10 passings per month. Nevertheless the declining trend is clear in Fig. 6.2.1 showing the 12-month moving average of monthly ship passings since 1981. It seems, however, that the decline has leveled off since last year. Detailed month by month changes are presented in Appendix 6.2.1.

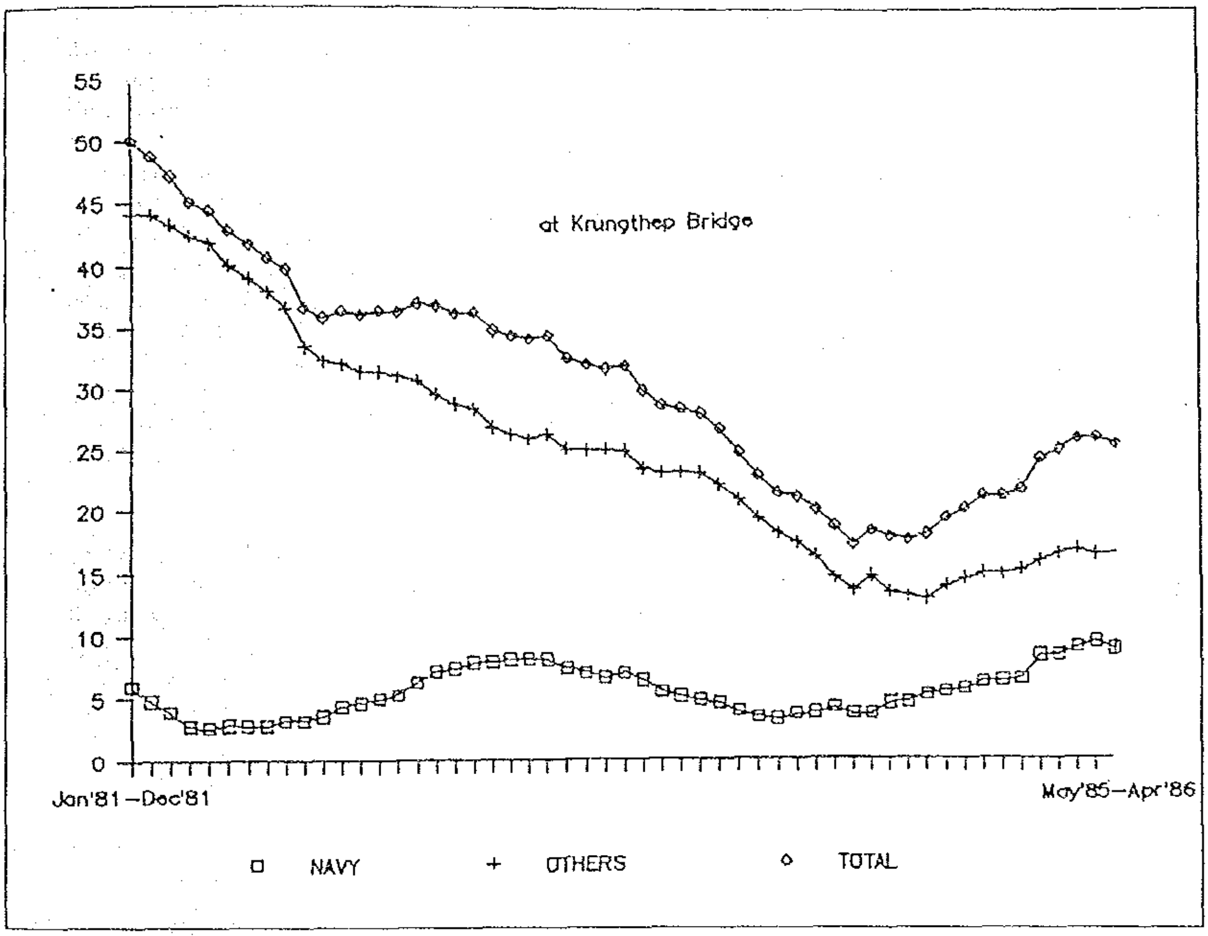


Fig. 6.2.1 12-Month Moving Avg. of Ship Movements

6.3 Ship Activities Upstream of the Bridge

1) Major Activities and Ship Height

It was possible to classify all ships recorded in the log book of the PWD maintenance office at the Bridge by means of ship names. Assistance provided by the maintenance office staff and the Harbour Department concerning this matter is greatly appreciated. The height of mast top from the waterline of each ship was then obtained from each of the agencies or companies concerned as ship registration records kept by the Harbour Department did not include the mast height. The mast top heights of all recorded ships were also estimated by the maintenance office staff relying on their memory of the visual impression of the difference between the mast top and the top of the opened Bascule bridge deck. The estimate height, however, turned out to be consistently higher than actual probably because of the parallax caused by looking up the mast top from below. The average difference and the standard deviation were calculated against those records for which actual mast heights were available. The resulting average was 3.6 m and the standard deviation 2.6 m. For those ships for which actual mast heights were not available, the mast height figure estimated by the maintenance staff was reduced by 1 m, the average difference less the standard deviation, to give conservative estimates.

Table 6.3.1 shows the number of ship passings classified by ship operator and by mast height. Actual numbers could have been significantly higher than those shown because of the single record book entry in the case of multiple ship passings as mentioned in the preceding section. Nevertheless, the general picture can be drawn from these tables.

Table 6.3.1 Number of Ship Passings

Total for Jan. 1984 through Apr. 1986

Owner/Mast in m	-10	-12	-14	-16	-18	-20	-22	-24	-26	-28	-30	30	NA	Total
Navy	40	12	17	31	13	12	6	5	11	5	2	0	5	159
Harbour Dept.	0	0	1	5	7	2	4	0	0	0	0	0	0	19
Fisheries Dept.	20	40	9	0	0	0	0	0	0	0	0	0	2	71
Marine Police	3	0	14	0	2	0	0	0	0	0	0	0	0	19
Customs Dept.	0	0	0	0	3	0	0	0	0	0	0	0	1	4
Port Authority	0	0	3	0	0	0	0	0	0	0	5	0	0	8
EGAT	0	0	0	0	0	0	7	0	0	0	0	0	0	7
Private Tankers	0	0	3	0	2	1	24	18	0	0	0	0	2	50
Harin Co.	0	0	5	53	24	0	0	0	0	0	0	0	9	91
Shaw Wanakit Co.	0	0	0	34	13	0	0	0	0	0	0	0	0	47
Other Private	0	1	13	0	26	10	1	8	0	0	0	0	5	64
Fishing Boats	0	19	13	0	0	4	0	0	0	0	0	0	2	38
Not Known	0	4	10	2	15	3	1	0	0	0	0	0	8	43
Total	63	76	88	125	105	32	43	31	11	5	7	0	34	620

The majority of ships coming upstream of the Bridge are for repairs. Table 6.3.2 compares the number of ships passed under the Bridge as obtained by dividing the number of passings by two and the number of ships repaired. Due to the under-recording at the Bridge the number of ships for purposes other than repairs turned out to be only 25% of the total.

Table 6.3.2 Ship Movements for Repairs and Other Purposes

(1985)

		Navy	Other Gov.	Priv.	Total
A.	Number of Ships Passed under Krungthep Br.	44	31	66	141
B	Bangkok Dock Repaired Ships	21	(4)	(18)	43
			22		
C.	Harin Co. Repaired Ships	-	(6)	(24)	30
D.	B.L.L. Co. Repaired Ships	-	(9)	(1)	10
E.	Repair by Mooring	23	NA	NA	23
F.	Balance A - (B+C+D+E)	0	12	23	35
G.	F/A (%)	0	39	35	25

Note: Figures in parentheses are estimates.

2) Bangkok Dock Co., Ltd.

The Dock is located just downstream of the Taksin (Sathorn) bridge.

Bangkok Dock Co., Ltd. is a State Enterprise, of which the largest shareholder is the Ministry of Finance. The management of the Dock is under the control of the Navy, which belongs to the Ministry of Defence (MOD).

Customers for repair and maintenance are approximately 20% from the private industry and 80% from the governmental agencies such as HD, PA, Marine Police, Customs Office and the Navy. Navy ships accounted for 50% of the total. The Navy has Thai Navy Dock for itself at Pomprachul near the mouth of the Chao Phraya river since 1981.

The facilities of the Dock are No. 1 dry dock of 3,000 GT, No. 2 dry dock of 4,000 GT and a slipway of 110 m, where about 400 skilled workers are working.

Records of ships repaired in recent years are summarized below.

Table 6.3.3 Ships Repaired in Bangkok Dock

Year	Height of mast (m)	-10	-12	-14	-16	-18	-20	-22	-24	-26	-28	-30	Total
1983	Navy Ships	7	1	1	14	2	1	0	0	1	0	3	30
	Other Ships	0	0	3	12	5	1	6	4	2	0	0	33
1984	Navy Ships	1	1	0	6	4	2	2	2	2	1	0	23
	Other Ships	0	0	1	0	3	2	9	5	0	0	1	21
1985	Navy Ships	2	2	0	3	4	4	0	1	6	2	0	24
	Other Ships	0	1	10	1	3	2	3	1	0	0	1	22
Total	Navy	10	4	2	23	10	7	2	3	9	3	5	77
	Other	0	1	4	13	11	5	18	10	2	0	2	76
	Total	10	5	16	36	21	12	20	13	11	3	7	153

3) Private Ship Repair Yards

Harin Ship Building Co., Ltd.

This company is an arm of the Harin Group which operates coasters from Bangkok to the South. Their slipway is located midway between the Krungthep and the Sathorn Bridges and capable of accommodating vessels up to 90 m long or with mast height of 24 m. The company currently employs 100 workers and is the largest and well equipped among private shipyards in this area.

Last year this shipyard repaired about 30 vessels, all of which were with masts of 15 m high or more. Some 80% were privately owned ones and mostly tankers. The rest were government vessels.

The management sees to tendency for larger vessels and, therefore, claims that a navigation clearance of 25 m would be sufficient for not altering their operation.

Last year the company inaugurated a new BOI promoted shipyard of 2000 gross tons capacity adjacent to and downstream of the existing Krungthep Bridge.

Mast heights of ships owned by the Harin Group are as follows:

Ship Name		Height (m)
Harin	2, 3, 5, 11, 23, 31, 37, 46, 48	15
Harin	20, 44	16
Harin	54, 56	17
Harin	1, 8, 59	18

The B.L.L. Shipyard Co., Ltd.

This company is located adjacent to the Harin Ship Building Co., Ltd. and owns one slipway capable of accommodating vessels up to 50 m long and an another slipway for vessels up to 30 m long.

In 1985, 33 ships were repaired on its slipways, among which 10 ships were of sizes requiring the opening of the Bridge. Most of ships were government vessels. Because of the limited capacity of the slipways ships which came to this shipyard had masts of 16 m in height at the most.

4) Marine Fisheries Division, Fisheries Department

Marine Fisheries Division of the Fisheries Department is located behind the pier belonging to the Fish Marketing Organization (FMO) at 89/1 Soi Supan Plu, Yanawa, about one hundred meters downstream of the Bangkok Dock. The pier is not used for unloading of fish for FMO any more, but as a base for research vessels of the Division. (Fishes are entirely transported to FMO by trucks from various parts of the country).

The Division has a considerable fleet of research vessels distributed among fisheries stations in many parts of the country along the Gulf of Thailand, among which six use the pier beside the headquarters as their base. Vessels are used in rotation and on an average 2 vessels are dispatched every month for the survey of fishery resources in the Gulf for a period of two to three weeks at a time.

Sizes of the ships belonging to the Division headquarters are:

Name	Length (m)	Mast Height (m)
Pramong 9	26	9.4
Pramong 4, 5, 2 and 11	23	11.0
Pramong 1	27	12.1

Movements of all the above vessels require the opening of the Krungthep Bridge. Pramong 1 has rarely been used because of high operating costs and low budget. A division official stated that a mast height of 11 m could be considered the practical maximum for the activities of the Division.

Off-shore fisheries research vessels belonging to the Fisheries Exploration Division occasionally come upstream of the Krungthep Bridge for repair work in the Bangkok Dock. Their base is at the Division's facility (jetty and anchorage) in Pak Nam. Their mast heights are:

Name	Mast Height (m)	Remark
Research 4	16	
Research 2	16	
Research 3	22	Early 1987

5) Shaw Wanakit Co., Ltd.

The company's main activity is to collect its own timber or log at ports of Surat or Songhla, to transport on one of its three ships to Bangkok, unload at one of its two sawmills, one at the foot of the Sathorn Bridge in Thonburi and another in Banglo in Yanawa, and market the lumber through many lumber dealers in Bangkok. Their ships call at the Thonburi sawmill three to four times a month, and at the Banglo sawmill about ten times a month.

Sizes of its ships are as follows:

Name	Length (m)	Width (m)	Mast Height (m)
Shaw Wanakit 9	46.10	8.47	17.0
Shaw Wanakit 11	42.70	8.54	14.66
Shaw Wanakit 15	47.45	8.40	16.0

Each ship is capable of carrying 500 tons of timber but normally carries 400 tons. Currently the Thonburi sawmill processes 1200 tons a month, but its capacity is 10 times larger.

6) Navy

The Royal Thai Navy is the largest single user of the Bascule system of the Krungthep Bridge. The purpose of navy ships coming upstream of the Bridge is limited only to repairs. In 1985 their ships came upstream 38 times, in total of which 21 were for repairs in the Bangkok Dock and the remainder of 17 were for minor repair work while mooring in the midstream of dockside. Judging from the actual records of recent past, the present level is in the high side as shown in Fig. 6.2.1.

The Navy has three dockyards of its own, one in Sattahip, one in Pomprachul at the river mouth, and one in Thonburi. The third one is meant for only small ships which can pass under the Memorial Bridge (navigation clearance 5.3 m).

The initial intention of the Navy when the Dockyard in Pomprachul was planned was to accommodate all dockyard work needs of the Navy ships between the Sattahip facility and this dockyard. However, to date, simple repair works have been left to the Bangkok Dock. Pomprachul facility has taken care of sophisticated works, and its staffing level and equipment are commensurate with the work load. Navy officials, however, expect that under the normal strengthening program the Pomprachul dockyard will have sufficient capacity to accommodate extra 40 ships per year within 5 years.

From the Navy's viewpoint it is preferable to site the Bangkok Dock, if to be moved, either next to the Pomprachul dockyard within the Navy's land, or at Laem Chabang, to eliminate lengthy and unsafe voyages up the River and through the bridge.

7) Harbour Department

Aside from small craft, the Harbour Department owns 7 ships which come upstream of the Bridge mostly for repair purposes and sometimes for mooring. Department officials maintain that the possible closure of the Bridge would not cause much inconvenience.

Mast heights of its ships are listed below.

Name		Height	Name		Height
Chao Tha Khor	2	17	Chao Tha Sor	1	14.5
Chao Tha Khor	4	18	Chao Tha Sor	2	15
Chao Tha Khor	8	21.3	Jor 1 (Tug)		20.5
Chao Tha Khor	6				

8) Others

Other activities involving movements of large ships upstream of the Bridge are limited to occasional mooring in midstream or at wharf-side that can be done downstream without causing significant inconvenience to operators. A tugboat has its normal berth a few hundred meters downstream of the FMO pier.

An additional field survey was made in September 1986 to investigate the possible effects of setting the navigation clearance at 7.5 meters instead of 12 meters, the same as for the Sathorn bridge. Location map of facilities is shown in Fig. 6.3.1. It was found that there was no activity of significance upstream of the Sathorn bridge requiring the navigation clearance at the Krungthep bridge higher than 7.5 meters. This point was later confirmed by the Harbour Department in the form of a letter to PWD.

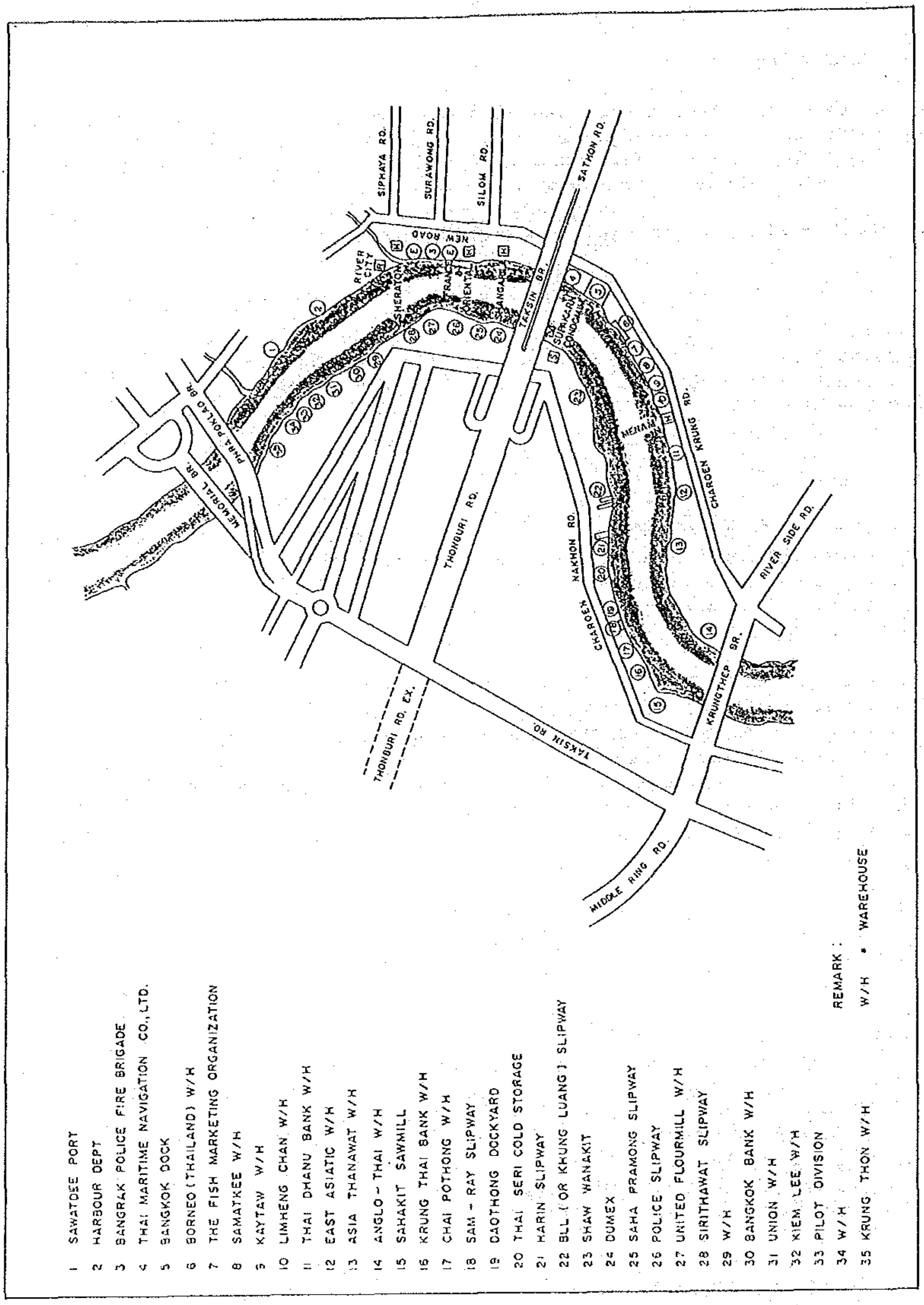


Fig. 6.3.1 River Facilities between Krungthep Bridge and Phra Poklao Bridge

6.4 Effects of Mast Height Restriction

6.4.1 Effects of Restriction on Individual Operators

If the new bridge puts some restrictions on mast height, effects will vary depending on the allowable mast height. Fig. 6.4.1 illustrates the percentage of all ship movements which currently require the Krungthep Bridge opening and which will be barred from this waterway under various maximum mast height limitations. If the limit is more than 30 m, no ships will be affected. If the limit is less than 10 m no ships can use this waterway. At the maximum allowable mast height of 20 m, 22% of ships currently using this waterway and requiring the Bridge to open will be blocked. At 16 m of maximum height, 62% will be clocked.

Individual operators will be affected at a varying degree. Fig. 6.4.2 shows the maximum mast height figures for each operator at which a maximum of 10% of ships involving its operations are blocked.

Bangkok Dock Co., Ltd. requires a maximum mast height limit of 25 m in order that 90% of their operation is not affected. The same applies to the Navy, the largest customer of the Bangkok Dock.

Harin Ship Building Co., Ltd. requires 23 m for the maximum mast height limit for not significantly reducing their operation, whereas the B.L.L. Shipyard Co., Ltd. would not need to alter their operation if the maximum is set at 16 m.

Fisheries Department can operate without much changes under a limit of 12 m, but Shaw Wanakit Co., Ltd.'s twice to thrice monthly timber supply operation cannot continue as they are now unless the limit is set over 17 m.

6.4.2 Possible Moving of Facilities

As examined in the preceding section, a complete closure of the existing Bascule bridge will necessitate moving of virtually all operations described in Section 3. Leaving the existing Bascule and constructing a new bridge with limited navigational clearance will give the existing operators a choice of moving entirely or partially.

Bangkok Dock Co., Ltd.

Since the Bangkok Dock Co., Ltd. is a state enterprise, the moving of its facilities will require a cabinet approval. The new site preferred by the navy is either next to the Navy's own Pompachul dockyard or within the complex of the planned Laem Chabang Deap Sea Port. In the former case, land would probably be available at no cost but would require substantial cost for foundation due to poor soil. In the latter case land acquisition will be substantial although probably within the property of the Port Authority of Thailand, but the foundation cost will be lower. Order-of-magnitude cost estimates totalling 500 million Baht are shown in Appendix 6.4.1.

Construction period would be in the order of three years.

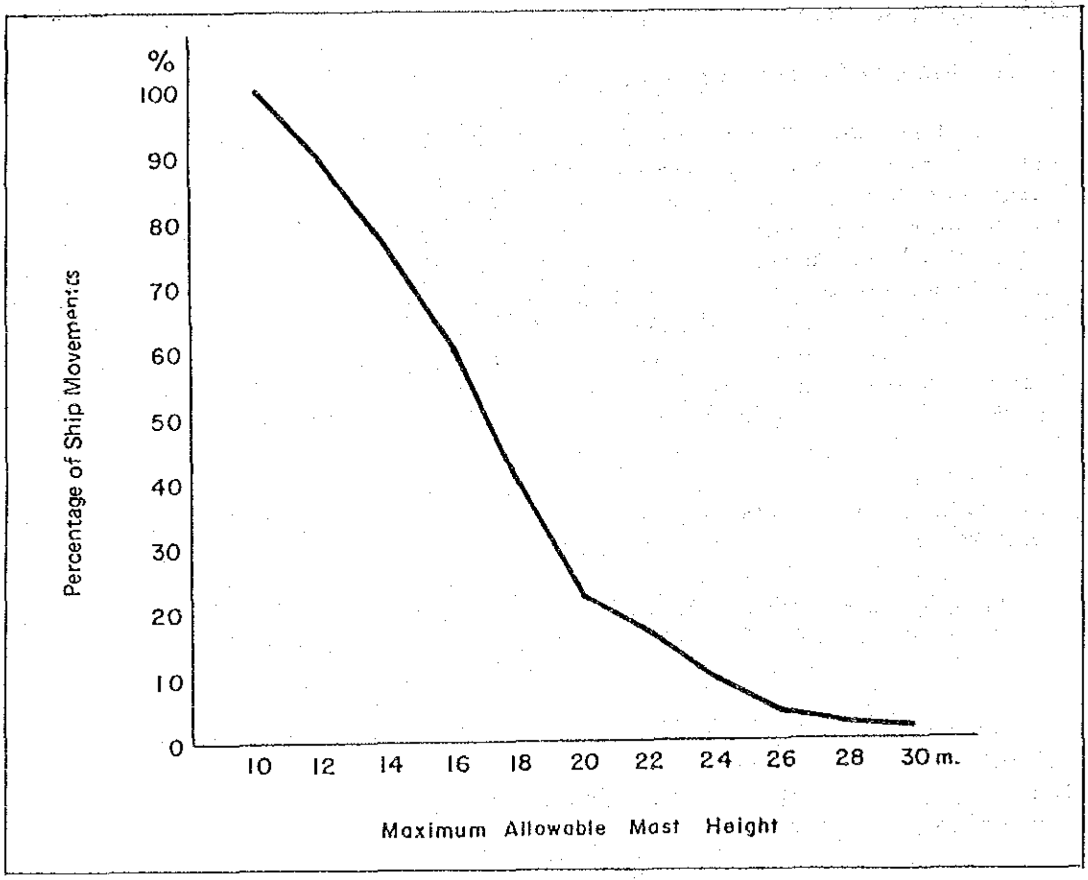


Fig. 6.4.1 Percentage of Ship Movements with Masts above the Maximum

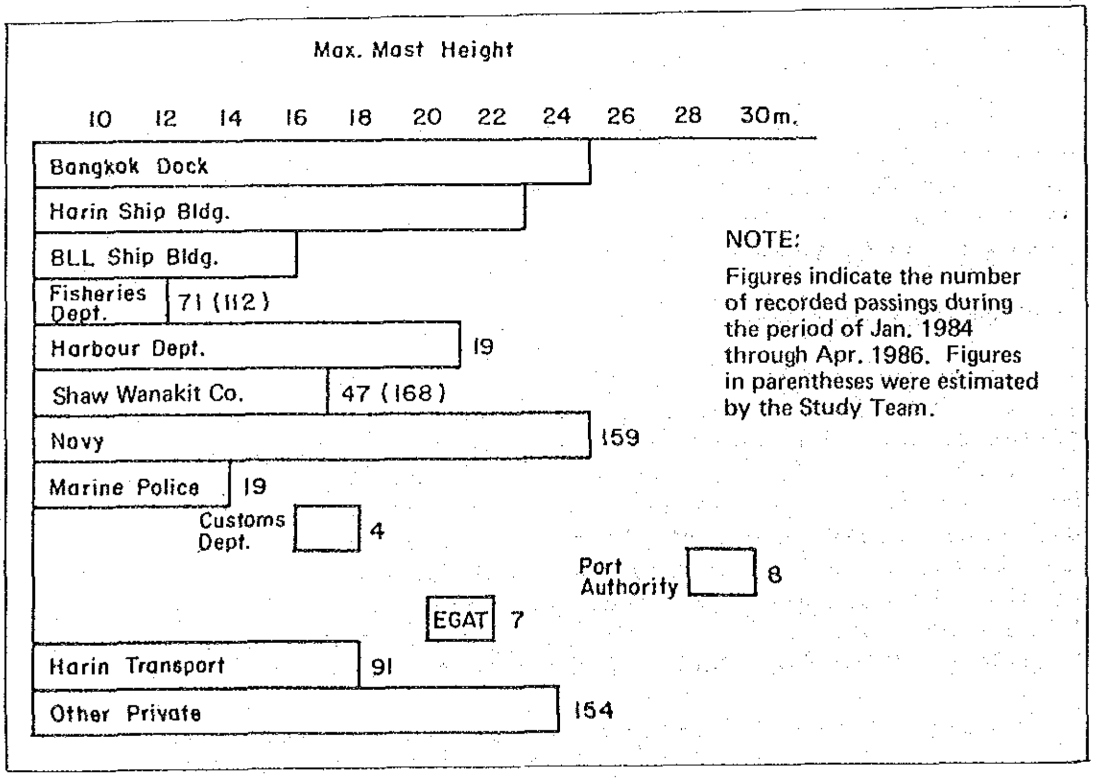


Fig. 6.4.2 Mast Height Limit at which 10% are Affected

It is possible to offset the above construction cost by selling the land of the existing dock as the land value of the prime river front property in this area with a total of 35,000 square meters could be 550 million Baht (assuming Baht 60,000/sq.wah). The land ownership, however, is held by the government and not by the Company. Some arrangement will be necessary to transfer the land sales profit to the investment in the new dockyard.

From the operational viewpoint the Navy would welcome such moving as stated in Section 6.3 (6). Private ship operators would also prefer such move for the same reason.

Private Ship Repair Yards

Officials of the Harin Group stated that in the event of the closure of the Krungthep Bridge the new dock adjacent to the Bridge would have to be expanded, including possible acquisition of adjacent land. Their headquarters would probably remain at the present site, creating communication and logistic problems to the company.

The B.L.L. Shipyard would be placed in a difficult position because of its small scale. The whole operation of the company will probably have to be moved if the management wants to stay in the business.

Marine Fisheries Division, Fisheries Department

It is clearly out of question to move the Division. The Division's facility at Pak Nam will have to be expanded to accommodate additional six survey vessels. Samples unloaded by the survey vessels will have to be transported by trucks.

Shaw Wanakit Co., Ltd.

The company will face a choice of closing down the Thonburi sawmill altogether and relying solely on the Banglo sawmill or leaving the Thonburi sawmill and transhipping timber at Banglo onto barges.

6.5 Navigation Clearance Requirements

Vertical Clearance

An official reply to PWD's request for the consideration of moving the Bangkok Dock downstream was made in a letter dated May 28, 1986 by the Navy Dockyard Division, the Royal Thai Navy. The letter was made available to the Study Team in early July. It states the following.

1. The Royal Thai Navy still requires to repair its ships at the Bangkok Dock in order to encourage this business of the Government and to retain this dock.

2. The maximum size of current navy ships is 2,540 tons, but in 1987-88 the maximum size will be 4,000 tons. The highest mast now is 31.00 m.

The contents of Sections 6.1 through 6.4 were put into an internal working paper titled "Internal Working Paper No. 1, Study of navigation Clearance" in late June and it was reviewed by PWD.

In early July 1986 the Study Team was verbally informed by PWD of their intention that ship movements through the New Krungthep Bridge should not be curtailed.

The vertical navigation clearance required to maintain the existing waterway traffic at the point should be 32 m including an allowance of 2 m according to the results of the Study Team's study. Preliminary alignment investigation revealed that at this height approach roads cannot be connected by at-grade intersection neither with the Taksin Road on the west bank nor with the Charoen Krung Road on the east bank. At both cross points approach roads will have to be raised to maintain at least 5 m of ground clearance.

The Navy indicated the increase in the maximum size of its ships to 4,000 tons. The maximum capacity of the Bangkok Dock is 4,000 tons. The case of ships of this size was considered. Fig. 6.5.1 shows relationship between the gross tonnage and the mast height. Although the relationship shown was based on data for cargo ships, it applies well for navy ships. The mast height of a ship of 4,000 tons would be 32 m according to the relationship. Ordinarily an allowance is required for vertical navigation clearance for:

a. exceptional high water
b. ship movement due to the wave
c. mast top elevation due to unbalanced loading
d. deflection of superstructure.

Items b. and c. above can be ignored in this case. Item d. above can be absorbed by the clearance between the central camber line and the upper navigational clearance limit line. For the item a. above, a value of 2 m can be considered sufficient. Therefore, the vertical navigation clearance of 34 m should be taken for the purpose of allowing the free passage of 4,000 tons vessels.

The difference between the superstructures for the navigation heights of 32 m and 34 m will be limited to the slight difference in grade of approach structures between the Taksin or Charoen Krung intersection to the center span because the height of approach structures at both intersections is constrained by the ground clearance. Difference in the construction cost between the cases of 32 m and 34 m would be very small.

Lateral Clearance

According to a report published in 1985 by the Japan Association for the Prevention of Maritime Accidents, necessary lateral clearance comprises the following:

a. Cruising Width
b. Wind Drift
c. Bank Clearance - clearance needed to avoid pressure caused by moving vessel and stationary structure
d. Ship Clearance - clearance needed between two moving vessels
e. Turbulent Flow Area Width - area of turbulent flow around stationary structure

Ship clearance is not needed in the case of the Krungthep Bridge. Others are not necessarily required to be added together for obtaining the total required lateral clearance.

Required lateral clearance figures were calculated by means of methods shown in the aforementioned report and shown in Table 5.5.1. The length of structure (pier) was assumed to be 30 m and its width 12 m. Wind drift clearance for the distance of 120 m which corresponds to the case of parallel bridges was also shown for reference.

However, the situation of the Krungthep bridge is more like that of waterways locks or canals. European standards of waterway locks are 1.5 m lateral clearance for river locks of 110 m long for ships of up to 1,500 tons and 5.0 m lateral clearance for ocean locks. Design standards for the proposed new Panama width of 60 m should be considered acceptable for ships of 4000 tons.

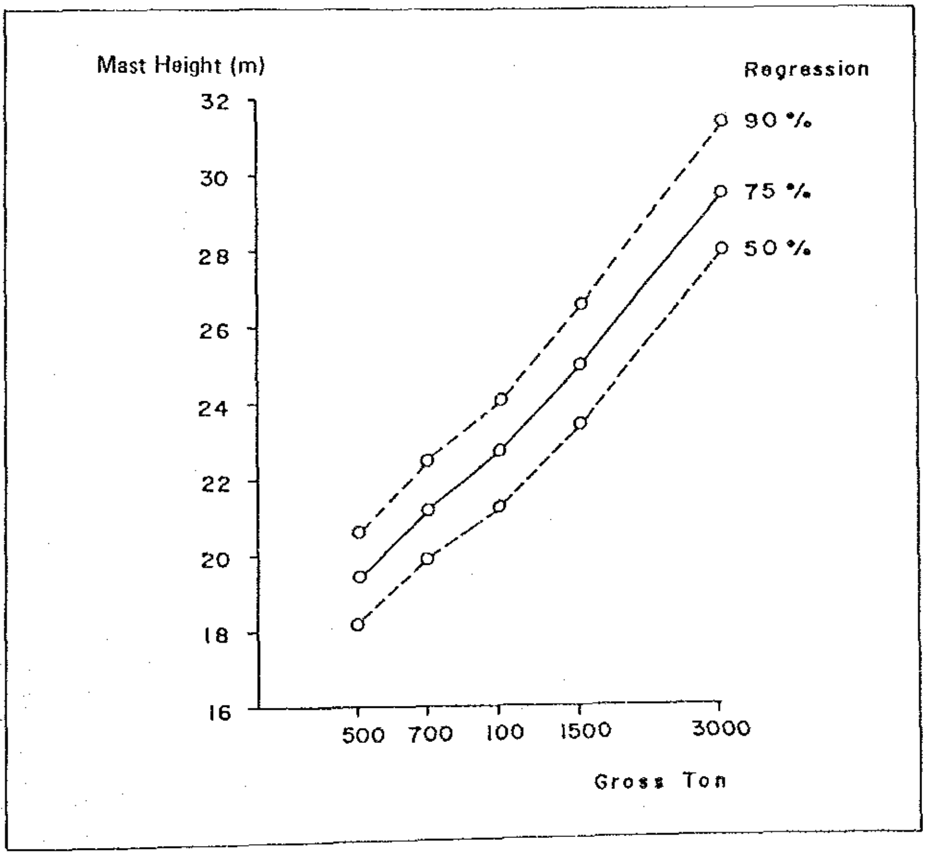


Fig. 6.5.1 Mast Height of Freighter (Light Load)

6.6 Navigation Clearance Adopted in this Study

The Navy, which is the only agency operating ships of more than 25 meters in height and is the main customer of the Bangkok Dock as well as being its mother agency, officially replied to a PWD's letter asking the possibility of relocating the dock downstream by a letter dated May 28, 1986. It is stated in the letter that the Bangkok Dock should continue to operate and that the maximum size of its ships would be 4,000 tons, requiring 32 meters vertical navigation clearance.

The Harbour Department consolidated various claims concerning navigation clearance in making its decision as shown in its official letter dated September 30, 1986. In the letter not only the vertical clearance but also the lateral and the channel configuration limits are specified. Table 6.6.1 shows the specified dimensions in the form directly quoted from the original letter.

Table 6.6.1 The Dimension of Ship Channel for (New) Krungthep Bridge

Distance from the existing Krungthep Br.	The ship channel	Horizontal Clearance (m.)	Vertical Clearance (m.)
Not over 60 m (the central or the bridge's width)	The central channel	68	≧ 5.2 can open or ≧ 32
	Adjacent channels	60	≧ 5.2
60 300 m upstream	The central channel	= the width of the central & the adjacent channel either side of the existing br.	≧ 32
60 300 m downstream of the existing br.	No pier in the river		≧ 32
300 m	No consideration		

Note: The position of the pier has to be the same as that of the existing bridge

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Request of HD are summarized below:

- New movable bridge is acceptable within 60 m either side from the existing bridge with horizontal clearance of 68 m in center, and 60 m in adjacent spans keeping vertical clearance of 5.2 m above H.W.L while close.

- Fixed high pier bridge is acceptable within 60 m in downstream side or within 300 m in upstream side with vertical clearance of 32 m.

CHAPTER 7

FIELD INVESTIGATIONS

7.1 Existing Conditions of the Surrounding Area

The existing Krungthep bridge forms a part of MRR which is one of the arterial roads of Bangkok and intersects some other secondary arterial roads as shown in Fig. 7.1.1.

MRR is now under construction by BMA and nearly completed except the flyover bridge crossing over the Mahachi Railway.

MRR has a 8-lane carriageway and sidewalks in both sides in the section from Taksin intersection to the north. However from Taksin intersection to the southeast including the existing Krungthep bridge, it has a 4-lane carriageway.

As for other arterial and secondary roads, the Taksin an Charoen Nakhon roads have 6-lane carriageways while the Charoen Krung road has a 4-lane carriageway. The Charoen Krung road ends nearby at the east bank of the Chao Phraya River.

The surrounding areas of the above mentioned roads are categorized as an urbanized commercial area, and many buildings of three (3) to four (4) stories are built up along the roads except for the sections of the approach road of existing bridge and that from the nearby Taksin intersection to the north. Especially the area along the Taksin Road is very crowded with buildings for stores and residences.

7.2 Soils and Materials Surveys

7.2.1 General Geology of the Area

The project area is known as the Lower Chao Phraya Basin. This river basin is bound on the east and west by mountain ranges, on the south by the Gulf of Thailand and on the north by a series of small hills dividing it from the Upper Central Plain with the Chao Phraya river as an inter-connector. In this area, the alluvial deltaic and marine deposits are the predominant geological formation.

The top of the recent marine clay is a weathered crust which has been subjected to the alternating desiccation and other physical and chemical weathering processes. The most recent marine transgression is thought to have occurred between 15,000 and 6,000 years ago and extended s far north as Ayuthaya. At this time the Bangkok area was covered with soft marine clay up to 24 meters thick in places. This clay is normally referred to as soft Bangkok clay. The underlying stiff clay was exposed to the subaerial processes of desiccation and oxidation before burial by the soft clay. Alternate strata of sand, gravel and clay follow the stiff clay extending several hundred meters depth before encountering the bed rock, and are known as the Quarternary deposits.

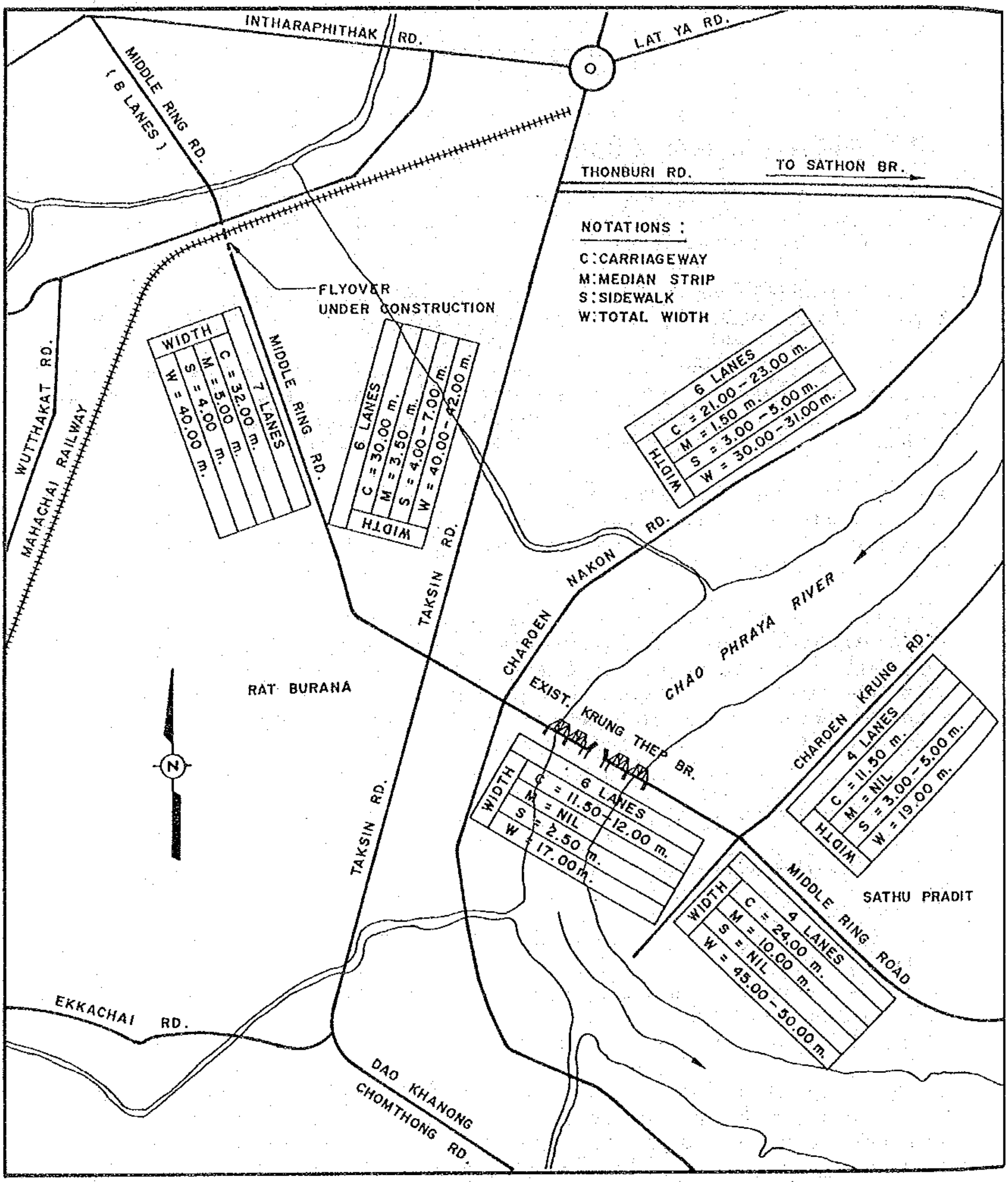

Fig. 7.1.1 Existing Roads around Krungthep Bridge

7.2.2 Location of Boreholes

The soil investigation including field boring and laboratory testing was entrusted to a local Consultant, Asian Engineering Consultants Corp. Ltd. and was carried out from Augsut to September 1986.

Three boreholes (A1, A2 and A3) were drilled to a depth of 70 meters below MSL in the vicinity of the existing Krungthep Bridge. Among these boreholes, one boring (A1) was performed in the Chao Phraya river. The location of each borehole is shown in Fig. 7.2.1.

7.2.3 Results of Field Borings

Boring logs and basic properties of laboratory test results for Boreholes A-1 to A-3 are shown in the separate volume entitled Drawings. The summary of test results and detailed laboratory test results are presented in the Subsurface Investigation Report. The soil profile has been prepared based on the surveyed data and is shown in Fig. 7.2.2.

The soil profile along the New Krungthep bridge route indicates that the soft clay stratum varies from the depth of 13.0 m to 22.0 m below MSL from the west bank to the east bank respectively. This soft clay is underlain by a 7.0 m to 13.0 m layer of stiff to very stiff silty clay which extends to the depth of 26 m to 29 m below MSL. The alternate strata of dense to very dense sand and the hard silty clay are encountered below the layer of stiff to very stiff silty clay. A lense of very stiff to hard silty clay which is less than 1.0 m in thickness, is encased in the 13 - 15 m stratum thickness of dense to very dense fine sand at the depth of 35 m below MSL. The pocket of clayer fine sand is occasionally found in soft clay or in first stiff to very stiff silty clay stratum.

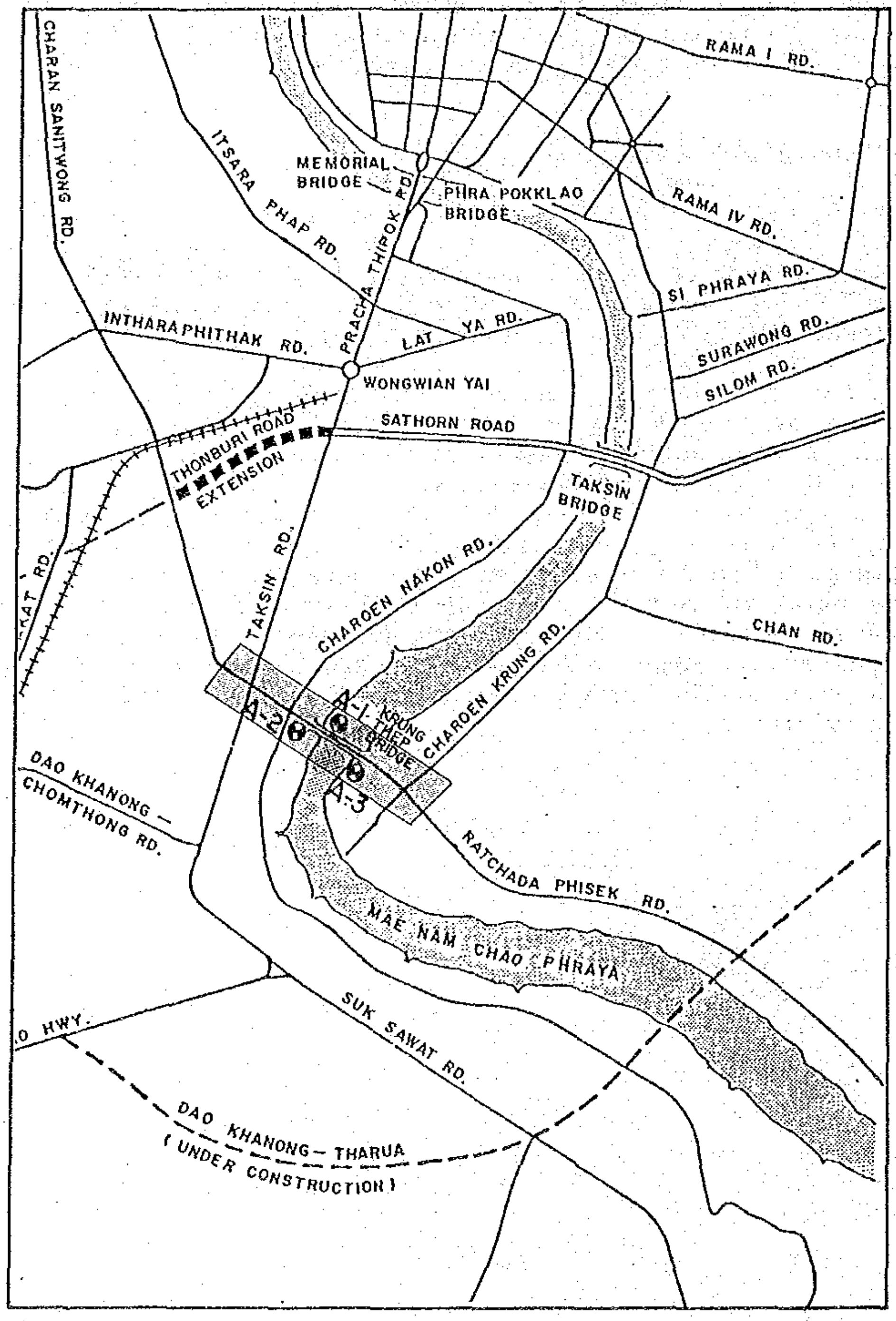

Fig. 7.2.1 Location Map of Boreholes

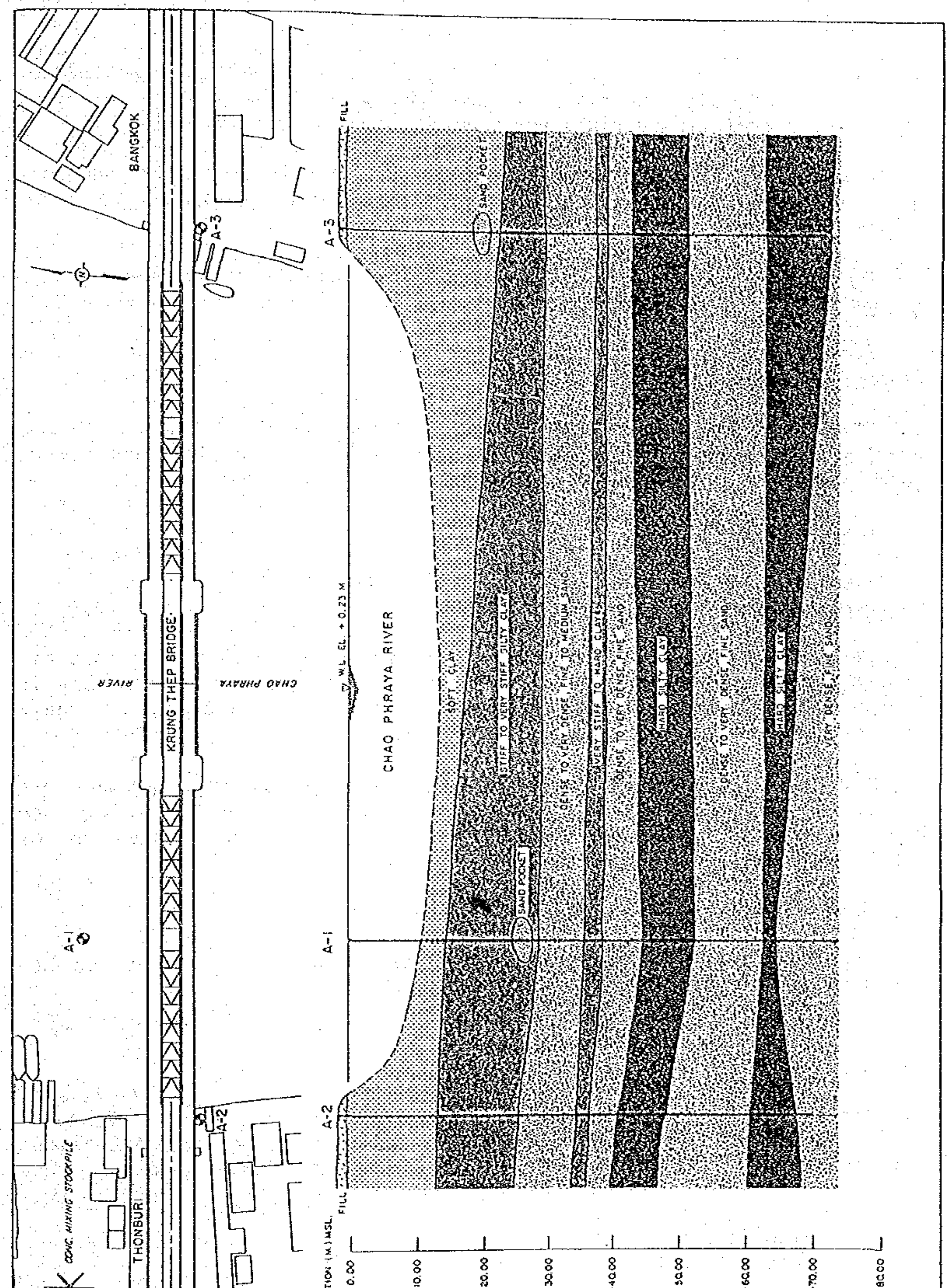

Fig. 7.2.2 Soil Profile along New Krungthep Bridge Route

7.2.4 Materials Surveys

1) Embankment Materials

In the vicinity of the project area, two kinds of embankment materials, laterite and sand, are available. The Study Team inspected and sampled typical materials for test.

Samples of laterite were chosen at Bo Din Thong and Bo Subsomat about 4.5 and 5.0 km respectively offset from Highway No. 21, Km 5+000 on the right near Saraburi.

Samples of sand were taken from the land deposit at Bo Kum Thong in A. Kamphaeng Saen, Km 5+600 Highway No. 3040 offset 3 km on right side.

Both CBR tests results showed very high value of 20% to 40%, proving it to be good materials.

The Study Team selected the sand as embankment material due to the shorter haul distance of about 85 km as compared with the laterite of about 165 km.

2) Rock Material

Rock is a key material for crushed aggregate for concrete and subbase course.

The Study Team inspected quarry sites at Chonburi and Ratchaburi. Most of rocks can be classified as limestone which poses no problem in course aggregates suitable for use in concrete works and subbase under the concrete pavement.

The Study Team judged the production of Ratchaburi quarry more preferable for the project due to huge volume of mountain quarry and haul distance of about 100 km which is shorter than that of Chonburi of 120 km.

3) Cement, Steel and Concrete Products, etc.

The main construction materials for bridge and road structures are produced or assembled and available in Thailand.

<u>Cement</u>

Almost all kinds of cement such as Portland Cement, Sulphate Resisting Cement, Rapid Hardening Cement and Low Heat Portland Cement are produced in Thailand and conform to Thai Industrial standards. Main cement factories are listed below as example:

Siam Cement Co., Ltd.;
Jalaprathan Cement Co., Ltd.;
Siam City Cement Co., Ltd.; and
Mahasiri Co., Ltd.

Steel

Original materials of such steel products as pig iron and steel scrap are imported, and main construction materials even prestressing tendons are manufactured in following firms, as example:

Siam Steel Co., Ltd. (SISCO);
Bangkok Steel Industry Co., Ltd.;
Thai Special Wire Co., Ltd.; and
Thai Steel Wire Co., Ltd.

However, shaped steel products are mainly imported through following companies: Kim Hong Seng, PH&D, Siam syndicate, Thong Seng Huad, Thai Mui Co., Ltd, Riboon Steel, Udom Metal Trading and Asian Steel Products etc.

Recently, Siam Machinery & Engineering Ltd. has been equipped to produce fabricated steel bridge structure of 700 tons per month for the requirements of the Wat Sai Cable-stayed Bridge Project by ETA. They have well trained workers in operation of factory machinery, welding of steel plates, fabrication of steel structures and quality control by local staff.

Concrete Products

Ready mixed concrete is readily available in Thailand through following plants:

Concrete Products & Aggregate Co., Ltd. (CPAC);
Metropolitan Concrete Products Co., Ltd. (MCON);
and Jalaprathan Concrete Products Co., Ltd. (JCC).

Precast concrete products including PC goods are also readily available in Thailand.

Wood

Timber products are supplied by following firms:

Kiat Anatachai, Siriwat, Lucha materials construction Co., Ltd., Sangviwat, Sangrungrote, and S. Chaiwattana Timber Industry etc.

Asphalt and Fuel

Asphalt are mainly imported, and not common in Thailand, and fuel are produced from imported crude oil and supplied by Shell, Esso, Apollo, etc.

7.3 Topographic Surveys

The geographical location of the proposed New Krugnthep Bridge is from 13°40'40" to 13°41'10" North Latitudes and from 100°30'50" to 100°31'20" East Longitudes. The surveyed area is located in a flood-prone area and the measured elevation of this low plain is less than 3.0 meters above MSL of the Gulf of Thailand.

The topographic survey was entrusted to a local consultant, Asian Engineering Consultants Corp. Ltd. (AEC) under the supervision of the Study Team.

This topographic survey included:

- Preparation of a topographic map (on a scale of 1:1,000) by plane table survey for areas of 335,500 square meters and 341,000 square meters in Bangkok side and Thonburi side respectively as already shown in Fig. 7.2.1.

- 2,020 m long profile levelling survey (1,020 m in Bangkok side and 1,000 m in Thonburi side) at 50-meter intervals along the existing road, including the additional levels at the top and bottom of abrupt changes in approach road of the existing bridge.

- Cross section survey at 50-meter intervals in the same places as the profile levelling survey.

From this topographic survey, the following were revealed:

- On Thonburi side, two (2) Chinese shrines are located in the vicinity of the abutment of the bridge. One is situated on the upstream river front at a distance of 10 m from the existing bridge structure and the other on the downstream side about 18 m from the wall face of the approach road.

- On Bangkok side, the governmental office of "CUSTOMS TRAINING CENTER" is located on the downstream river front side and this is a big advantage for the land acquisition for the Project. The project would require only a part of its open yard.

7.4 Hydrological Studies

7.4.1 Bathymetric Survey

The bathymetric survey was conducted in an approximate area of 200,000 square meters around the existing Krungthep Bridge, 250 meters both upstream and downstream from the center line of the existing bridge.

The results of the bathymetric survey is shown in Fig. 7.4.1. From this survey, the following were revealed:

- The stable Thaweg (main flow line) immediately upstream of the bridge is at an angle of about 60 degrees rather than at the right angle to the bridge.

- Immediately after passing the bridge site, the river's main flow line is bent to the right of the bridge line.

- There is no serious scouring upstream of the central piers. However, deep holes of u to minus 20 m were found at about 50 m downstream of the piers. It was comfirmed by the Harbour Department that these holes were not made by dredging which had never been done in the deeper river sections such as just downstream side of the Krungthep bridge.

7.4.2 Local Scour

In the planning of foundations and temporary cofferdam for bridges in a river, the magnitude of scour by which the riverbed is lowered adjacent to the structure needs careful consideration.

The maximum local scour depth was estimated at -30 m, or less, by using Laursen's formula, therefore, the existing deepest scour level of -20 m is judged to be about the 70% depth of the theoritical maximum.

The Study Team followed the river bed changes and made the Fig. 7.4.2 based on the past survey records.

The protection works against scouring seems to be sufficient by the method of pitching stones in the double range of the pier width. The stone-pitching work for protection by PWD in 1982 seems to show a satisfactory result.

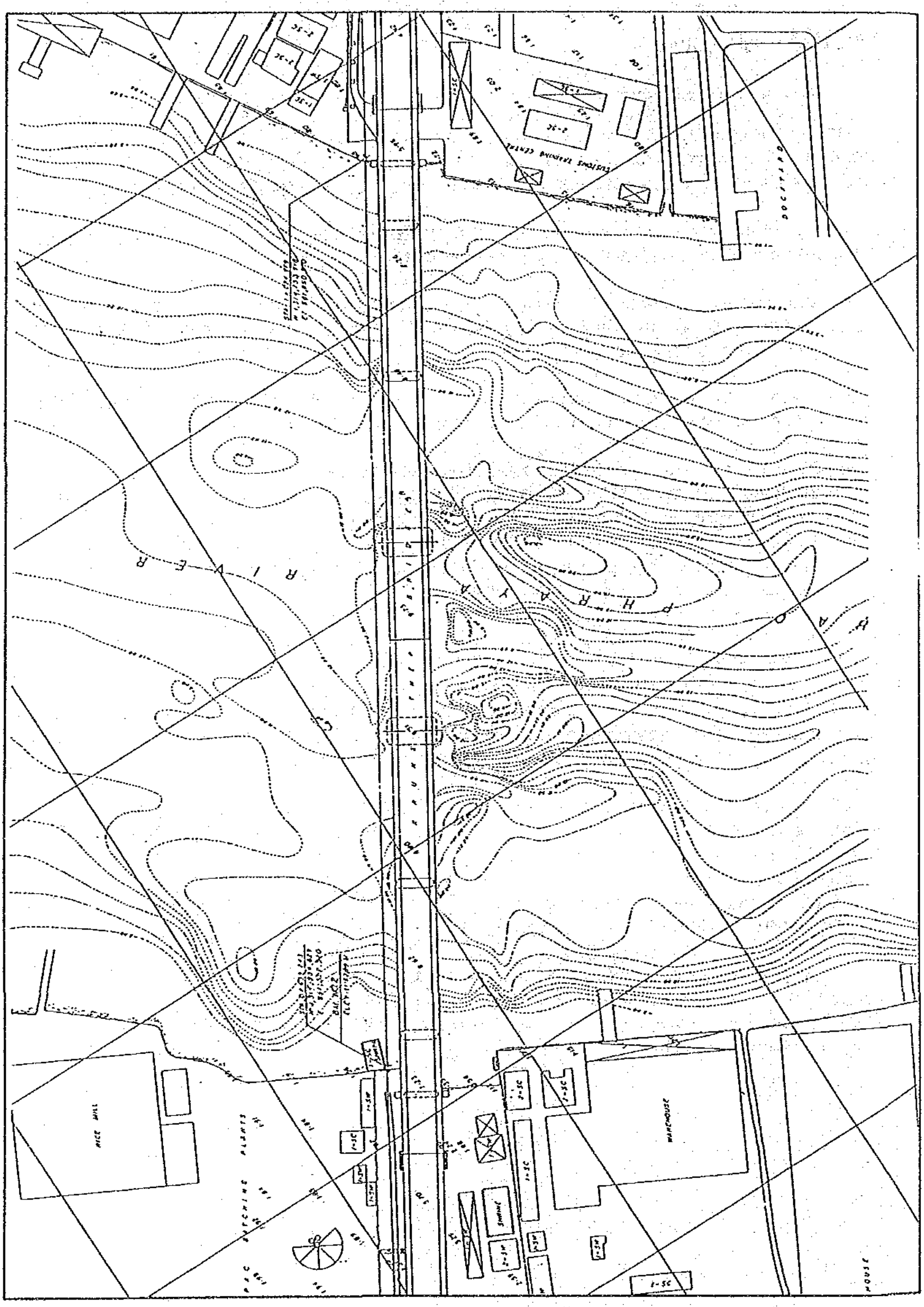

Fig. 7.4.1 Bathymetric Survey 1986

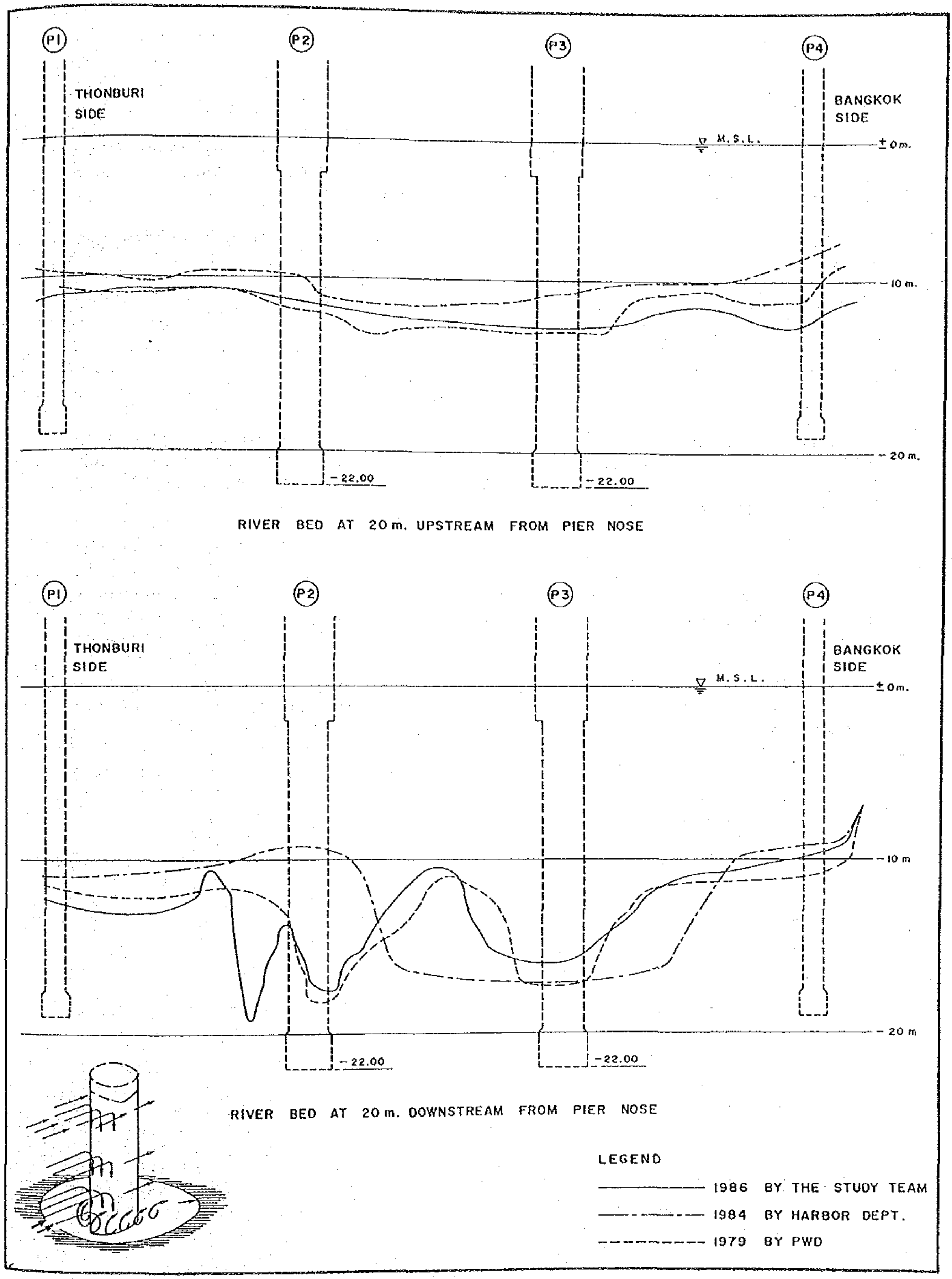

Fig. 7.4.2 Riverbed Changes around Krungthep Bridge

7.4.3 Other Hydrological Considerations

According to previous study reports on bridges over the Chaophraya River, the maximum flood volume is 4000 cu.m. per second, and the maximum local flow intensity is 3.0 m per second.

The present river section at the Krungthep bridge was surveyed and results are shown below:

Total river width	:	390 m
Maximum depth	:	- 14 m from M.S.L.
Flood level	:	+ 2.13 m
Water flow section	:	3,700 sq.m
Area obstructed by piers	:	650 sq.m (17.5%)

Any introduction of structures into the river channel generally affects both flow pattern and flow intensity which in turn may change the river morphology, the local channel geometry, and the relationship between water level and discharge.

The hydraulic geometry of a river channel can be described by the channel width, depth, cross-section shape, gradient and alignment. It depends on a number of factors which include discharge, characteristics of bed and bank materials, the amount of sediment transported by the channel and the ability of the channel to transport the quantities of sediment supplied from sources further upstream. There is no satisfactory method of calculating channel geometry which may be applied to all types of river. The detailed discussion of the above will be the subject in detail design stage, if necessary.

However, the maximum channel depth can be obtained by applying empirical multiplying factors to the mean depth. These factors are attributable to Lacey and are given in Table 7.4.1.

Table 7.4.1 Multiply Factors for Maximum Channel Depth

Location	Factor
Straight reach of channel	1.25
Moderate bend	1.50
Seven bend	1.75
Right-angled abrupt turn	2.0

The Project bridge is located at the nearly severe bend point, so that the mean depth downstream is about 1.6 times that upstream. From these considerations, the newly introduced additional piers should be as small as possible.

CHAPTER 8

BRIDGE LAYOUT ALTERNATIVES

8.1 Introduction

The task of determining the type of bridge for the expansion of traffic capacity at the existing Krungthep Bridge was complicated due to many conflicting factors, some of which had been unknown or uncertain until the later stage of the study. Factors taken into consideration included:

- Traffic capacity requirements;
- Form and degree of utilization of the existing bridge after the project completion;
- Navigational clearance requirements, vertical and lateral;
- Basic bridge type, movable or fixed;
- New bridge location and alignment;
- Heavy vehicle traffic requirements;
- Bridge access;
- Intersection layout;
- River hydrology;
- Land acquisition difficulty; and
- Construction cost.

Various alternative schemes were formulated and evaluated on the basis of the above factors, and schemes inferior to others were eliminated from further considerations. In the Progress Report (I) issued in May 1986, twenty-two alternatives were identified and preliminary evaluation was made. In the Progress Report (II) issued in September 1986 seven alternatives of A through G were identified and examined. They included low fixed bridge, low movable bridge, and high fixed bridge with varying uses of the existing bridge including its complete removal as shown in Fig. 8.1.1. Three alternatives, Alternative D, Alternative E and Alternative G, were selected for further study and the results were presented in the Interim Report issued in December 1986. This Chapter describes configurations of the three alternatives and how the final selection of the bridge layout was made through the examination of each against various planning factors listed above.

Note: Other Alternatives

-A. New fixed type 6-lane bridge with low piers replacing existing bridge.

-B. New fixed type 4-lane bridge with low piers utilizing the existing bridge as 2-lane bridge.

-C. New fixed type 3-lane bridge in first stage, after 10 years other fixed 3-lane bridge replacing existing one.

-F. New fixed type 6-lane bridge with high piers replacing existing one.

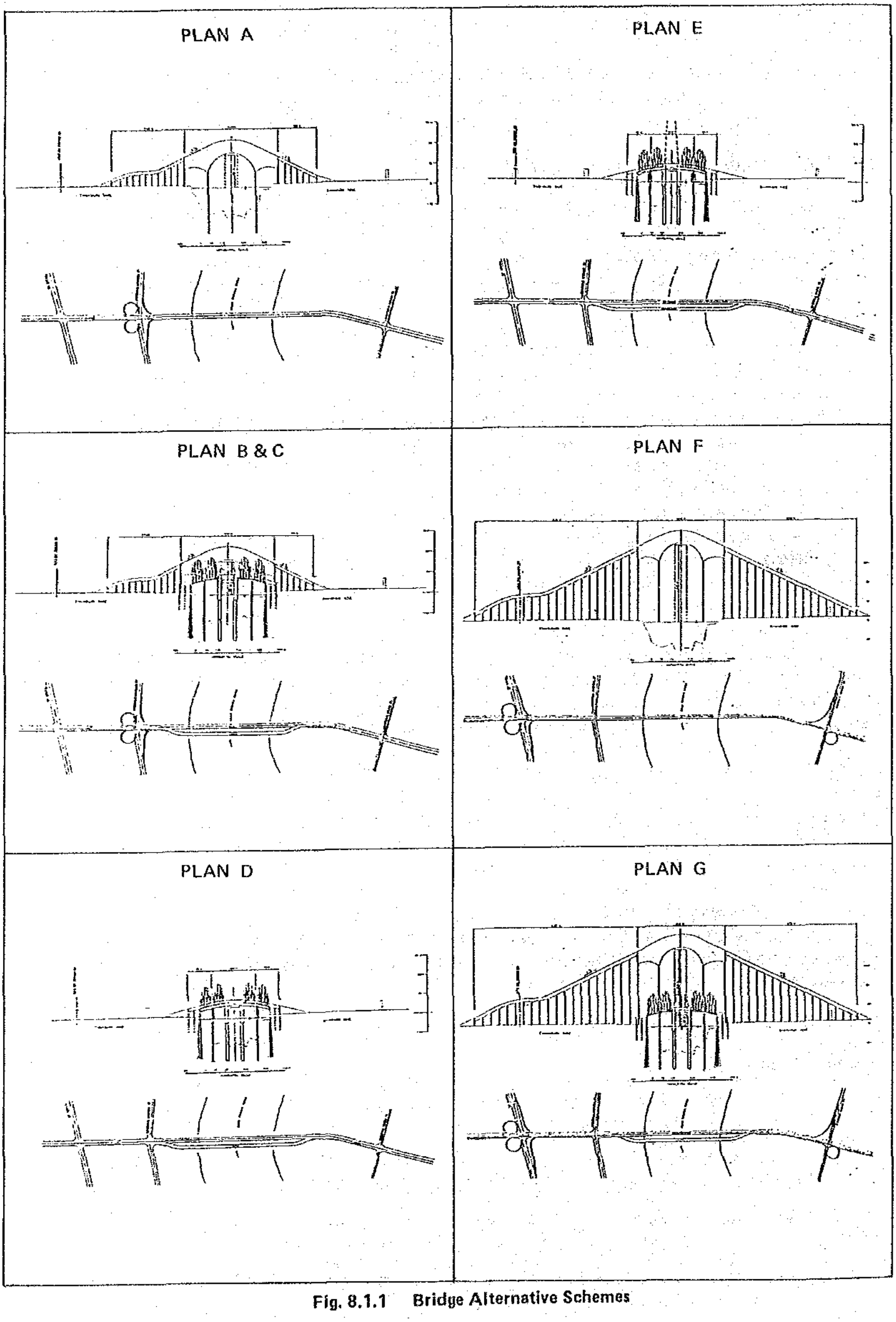

Fig. 8.1.1 Bridge Alternative Schemes

8.2 Description of Alternatives

Studies up to the Progress Report (II) lead to a conclusion that three alternatives, Alternative D, Alternative E, and Alternative G were those worthy of further considerations. Further subdivisions of these alternatives were made considering more details. Particularities of each alternative are summarized below:

1) Alternative D

This is a low fixed bridge type and presumes the removal of the Bangkok Dock and other major private marine facilities (two private ship repair slipways and a log unloading jetty). Three schemes of this alternative were considered as described below and shown in Fig. 8.2.1, 8.2.2, and 8.2.3.

i) D-1 Plan: The existing bridge is to be utilized as a two-direction 2-lane bridge for light vehicles only, without strengthening its structure. Trucks including trailers are to be guided through an additional access rampway to the new bridge, which is to be a 4-lane two-direction bridge downstream of the existing bridge.

ii) D-2 Plan: A pair of one-way 2-lane bridges are to be constructed on both sides of the existing bridge, for use of all trucks. The existing bridge is to be used as a two-way 2-lane bridge for light vehicles only.

iii) D-3 Plan: A new 3-lane oneway bridge is to be constructed. The existing bridge is to be strengthened and utilized as a one-way 3-lane bridge in the opposite direction.

The Harbour Department requested in their letter to PWD No. 0505/6082 dated September 30, 1986, that not only the center span but other spans should provide the minimum vertical clearance of 5.2 meters from the high water level for the sake of river transport. This requirement precludes the adoption of variable depth girder type. The most economical method to satisfy this requirement is the use of PC continuous box girder by the incremental launching method. The space for the segment casting yard is available in the river front on the Bangkok side.

2) Alternative E

This is a movable bridge type. River traffic can be maintained without change. Three plans were considered for this alternative.

i) E-1 Plan: The existing bridge is to be utilized as a two-way 2-lane bridge for light vehicles only. A new bascule or lift type movable bridge is to be constructed with additional rampways for heavy vehicles with the same layout as the Plan D-1.

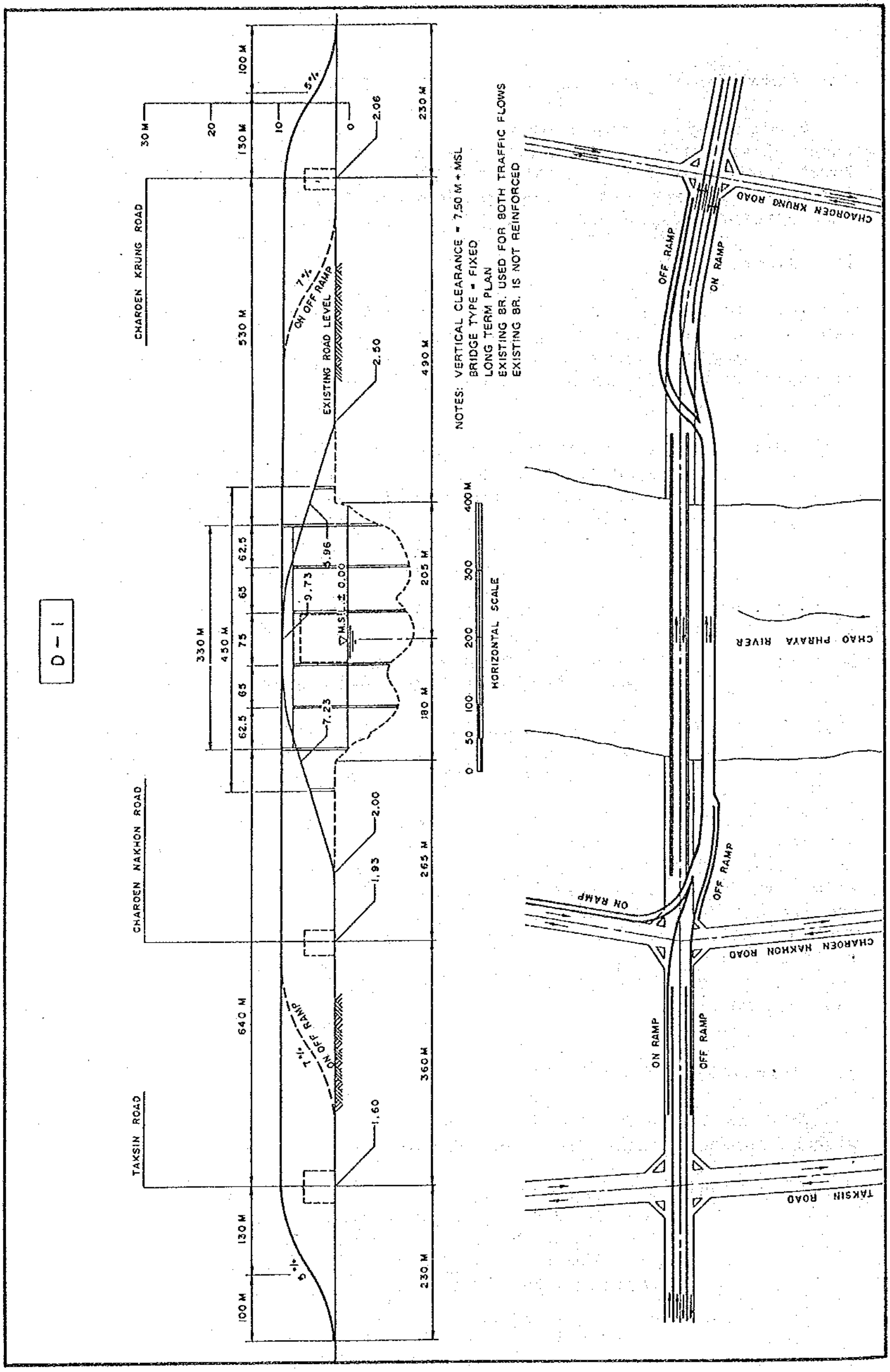

Fig. 8.2.1 Plan D-1

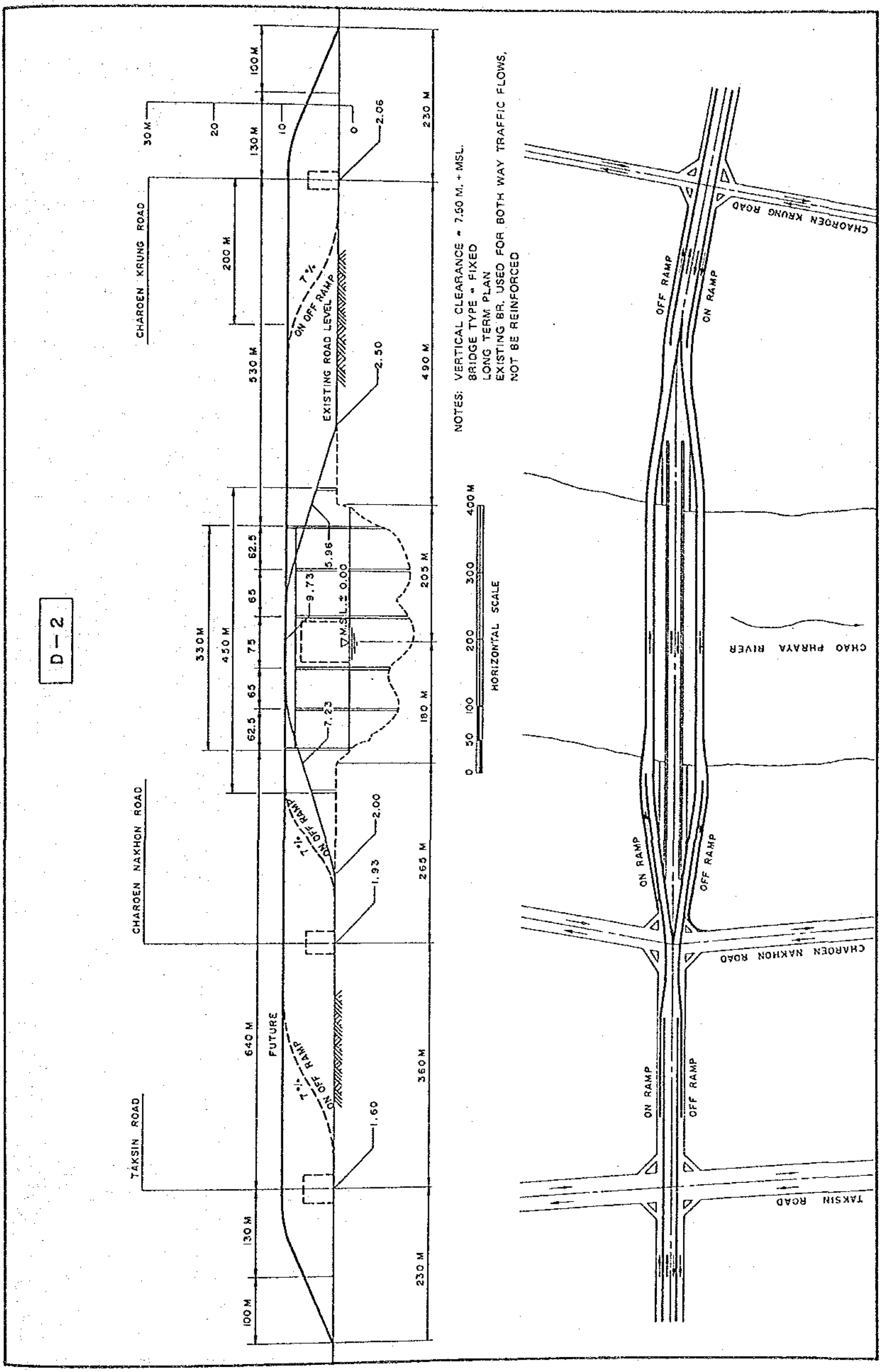

Fig. 8.2.2 Plan D-2

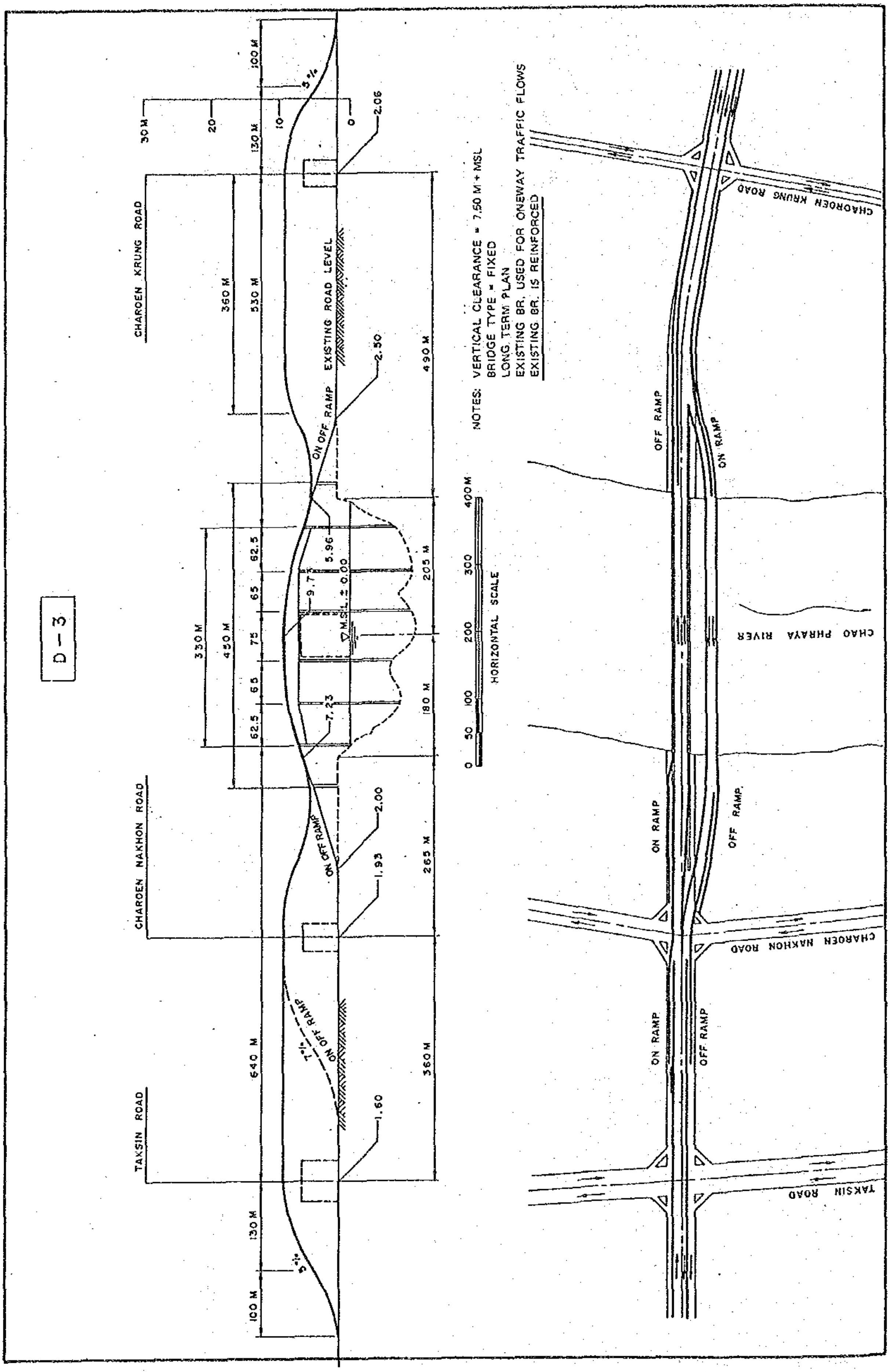

Fig. 8.2.3 Plan D-3

ii) E-2 Plan: Same as E-1 except that this is a swing type bridge instead of bascule or lift type. Maintenance costs would be lower than E-1.

iii) E-3 Plan: A pair of one-way 2-lane bascule bridges are to be constructed on both sides of the existing bridge, same as in case of Plan D-2.

Due to the heavy future traffic volumes through traffic lanes of the Middle Ring Road, all intersections were designed to be flyovers. For plans E-1 and E-3, however, a staged construction was also considered with full flyovers assumed to be constructed only by 2001 instead of from the beginning. Fig. 8.2.4 through 8.2.6 show Plans E-1, E-2 and E-3 with different stages.

Side spans of the new bridge(s) are expected to be of the steel box girder type to maintain the minimum navigation clearance of 5.2 meters. Use of PC continuous box girder by the incremental launching method cannot be applied because the center span is movable.

3) Alternative G

This is a fixed bridge type with a navigation height clearance sufficiently for not disturbing the river traffic. A plan named G-1 is shown in Fig. 8.2.7 which has the navigation clearance of 34 meters and the central span width of 220 meters. This type can be of PC box girder and constructed by the balanced cantilever erection method. Given additional conditions such as the minor restriction on the mast height, a bridge of this type with different dimensions such as a lower height can be considered.

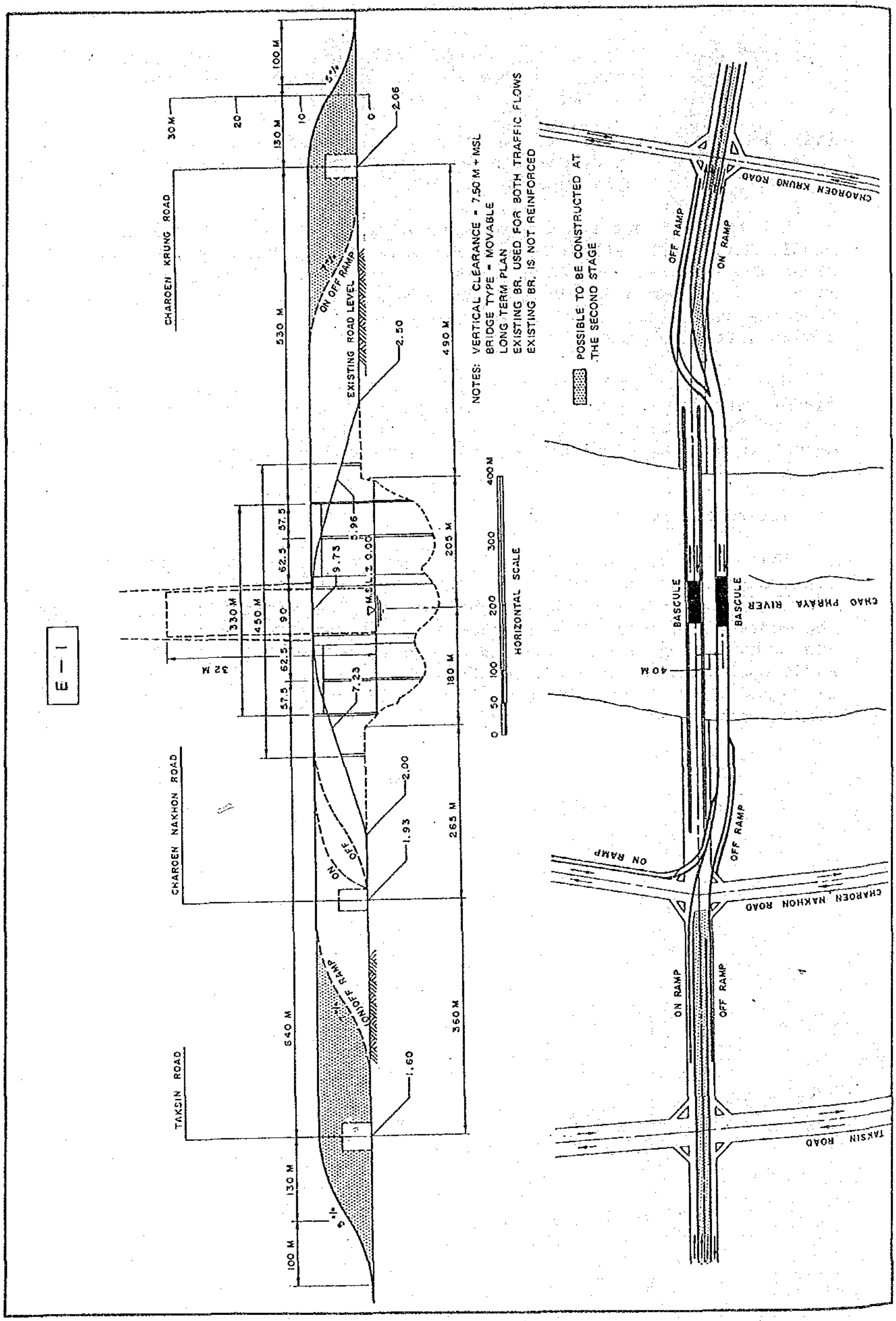

Fig. 8.2.4 Plan E-1

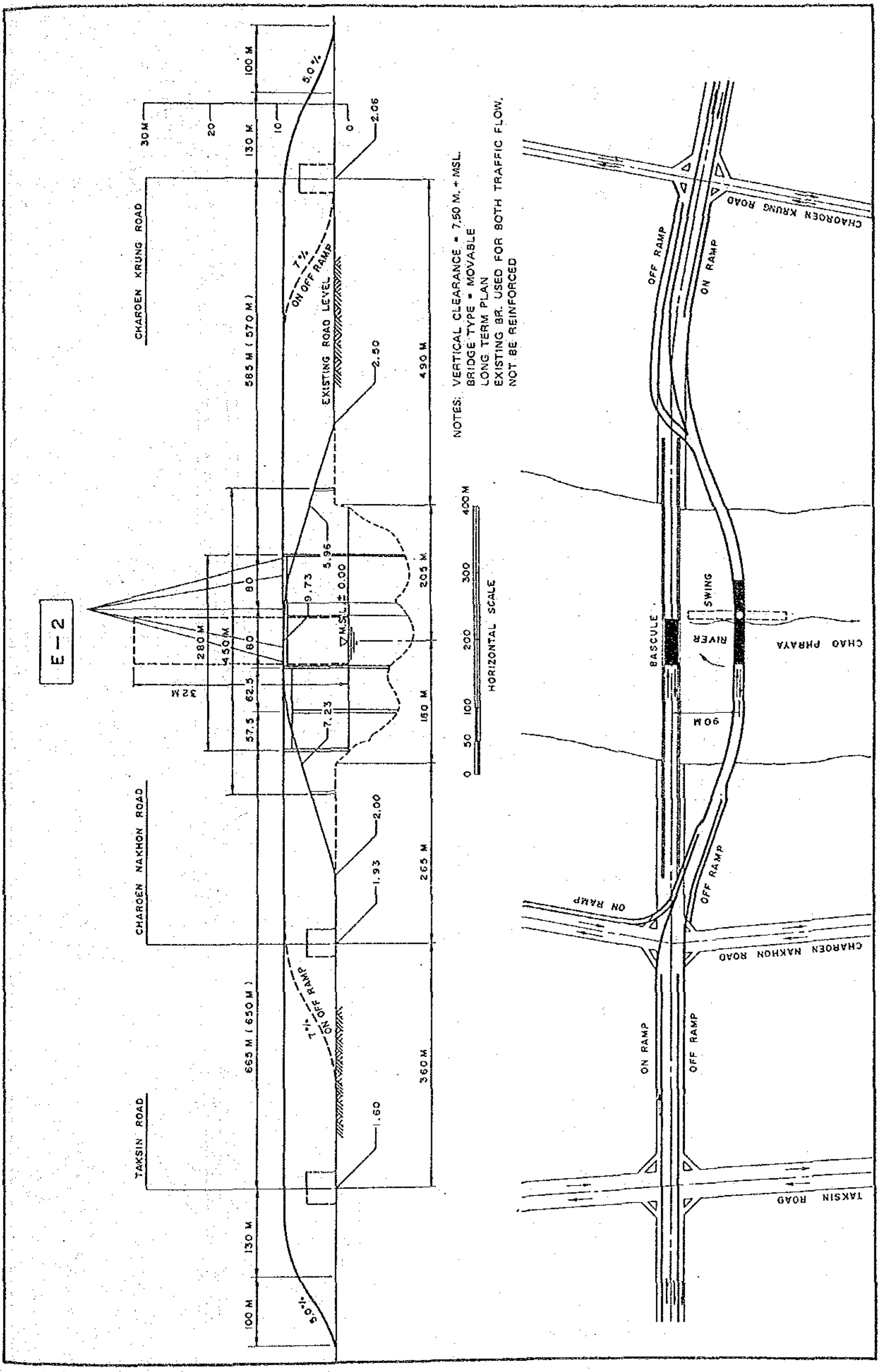

Fig. 8.2.5 Plan E-2

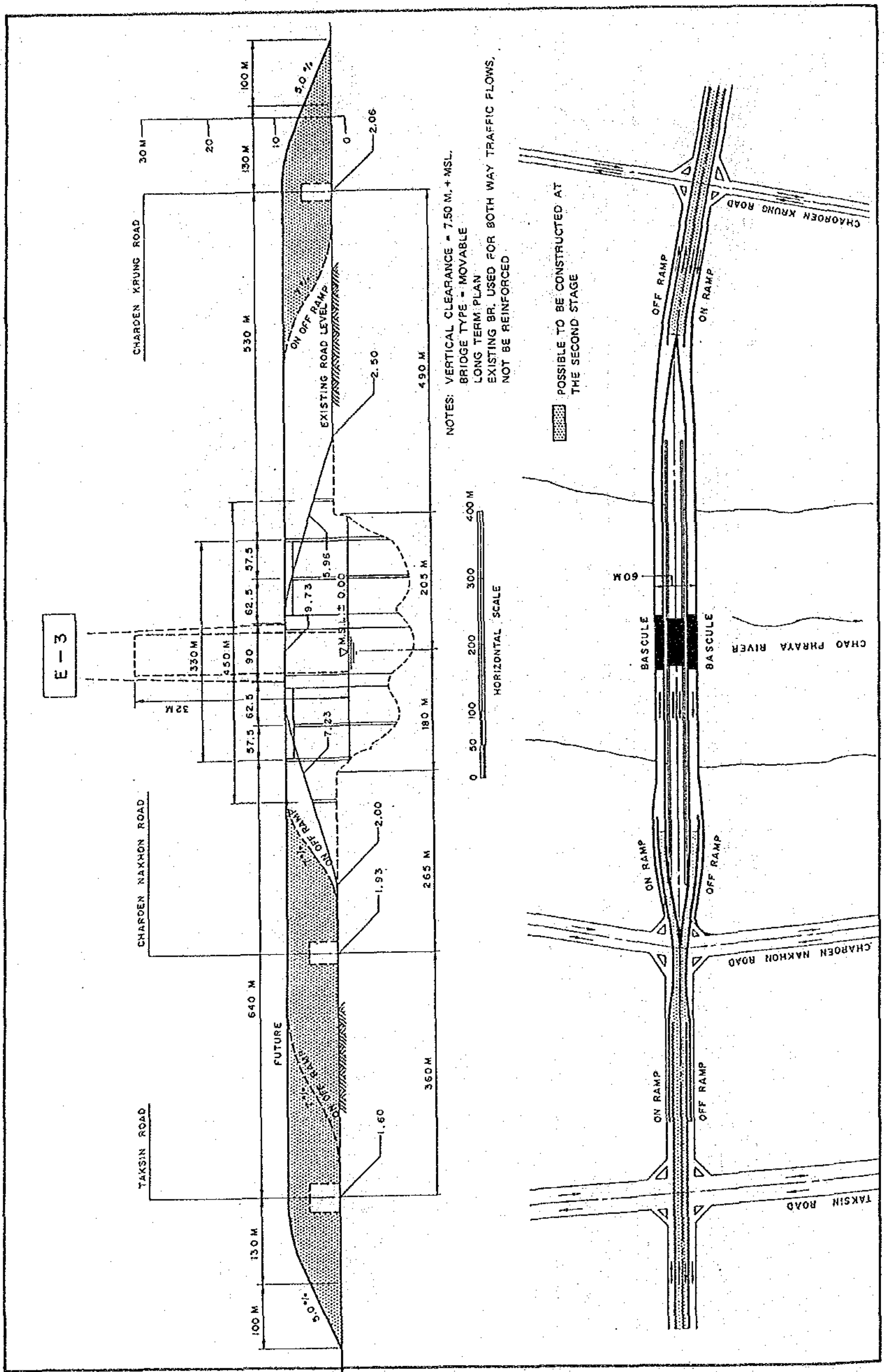

Fig. 8.2.6 Plan E-3

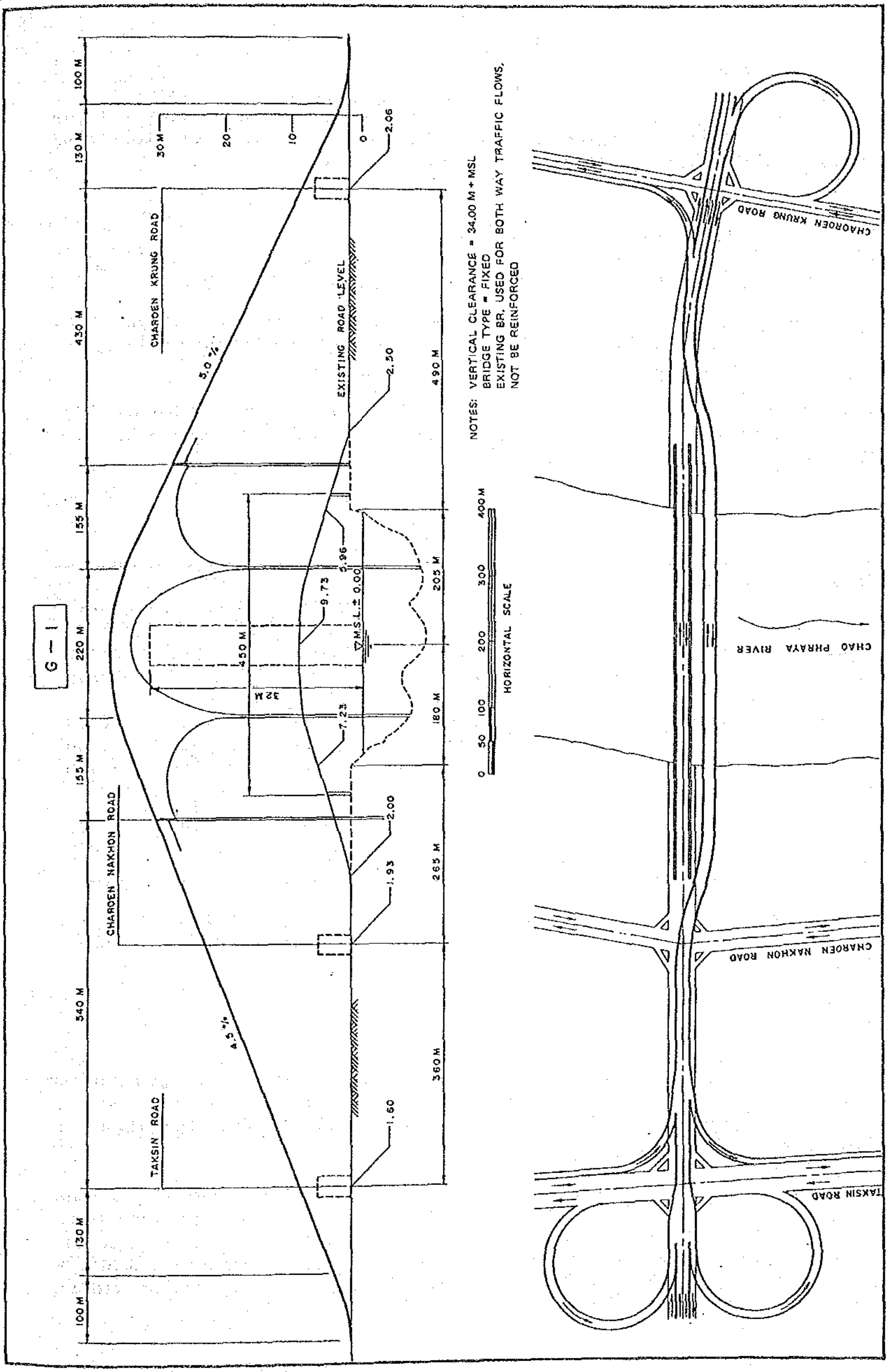

Fig. 8.2.7 Plan G-1

8.3 Bridge Planning Factors

Factors which should be taken into consideration in determining the bridge plan were identified and examined item by item. The following sections discuss implications of each factor.

8.3.1 Traffic Management

1) Traffic Flow Forecasts

Future traffic volumes were forecast for various alternative cases of the new Krungthep Bridge. The methodology of traffic projection has been discussed in Part II.

Forecast traffic volumes for the cases of low bridge and high bridge are summarized below in Table 8.3.1 and illustrated in Fig. 8.3.1 and Fig. 8.3.2 including turning movements.

Table 8.3.1 Bridge Traffic Forecasts

Bridge Type	Forecast Year	Time Period	Exist. or New	To Bangkok	To Thonburi	Total
Low	2001	Morning	Total	2,900	2,500	5,400
	2011	"	Total	3,000	3,300	6,300
High	2001	"	Exist.	600	700	1,300
			New	3,200	2,800	6,000
			Total	3,800	3,500	7,300
	2011	"	Exist.	700	1,600	2,300
			New	3,100	3,600	6,700
			Total	3,800	5,200	9,000

Note: Traffic to and from Charoen Nakhon Road can have direct access from and to the low bridge; but not to and from the new high bridge.

2) Truck Movements

The Krungthep bridge is the closest to the industrial concentration area along the lower Chao Phraya river among major bridges in Bangkok. Therefore, composition rate of heavy trucks has been high, more than 20% (excluding motorcycles).

According to the analysis results presented in Chapter 5, the structural strength of the existing bridge is not enough for the live load specified in HB-45 units and HA load. However, it is enough for the live load of TL-20 or HS-20. In the case that future heavy truck's axle loads exceed the TL-20 or HS-20 standards, heavy trucks should be led to a new stronger bridge.

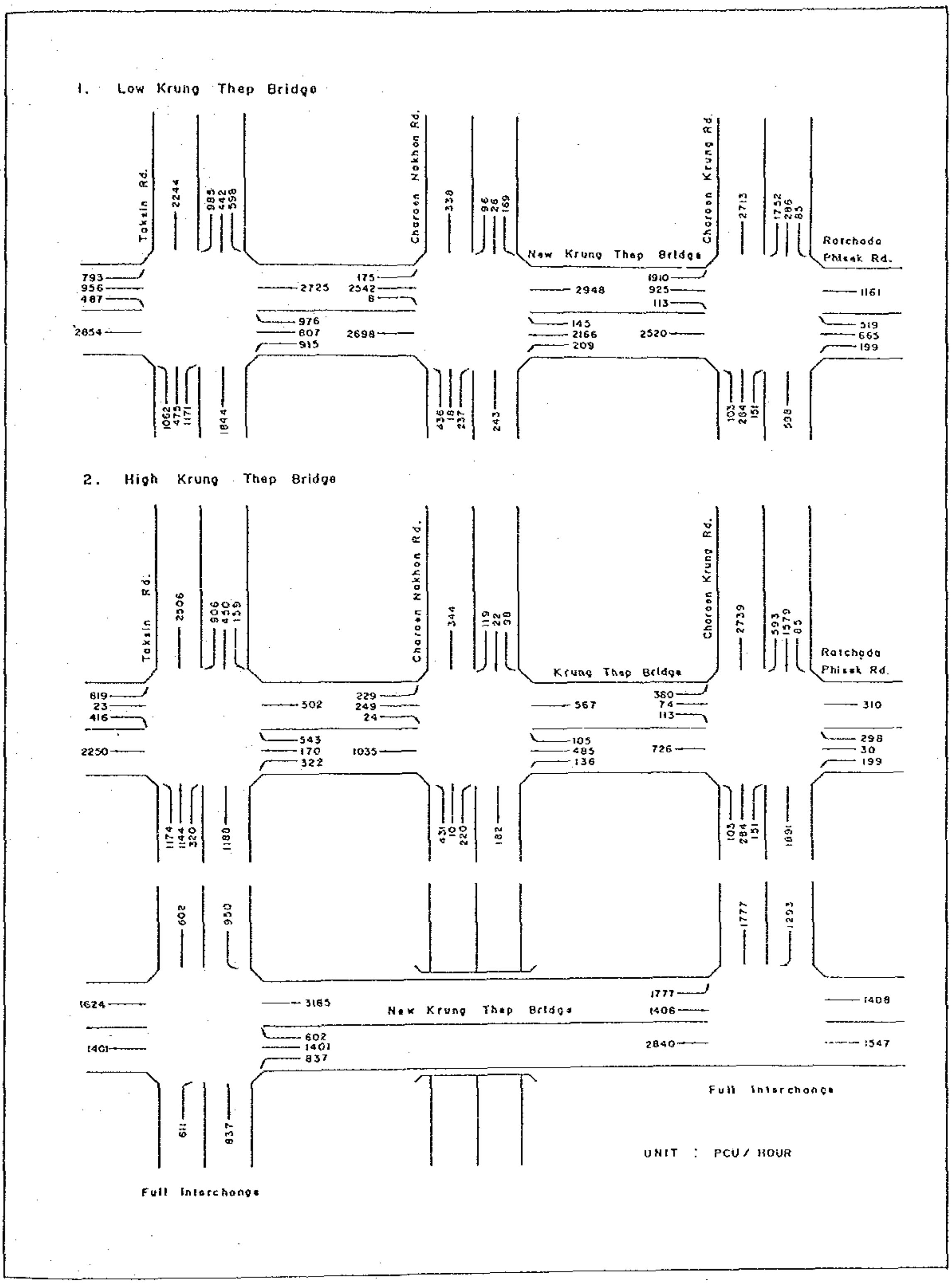

Fig. 8.3.1 Turning Movements in 2001 (Morning Peak)

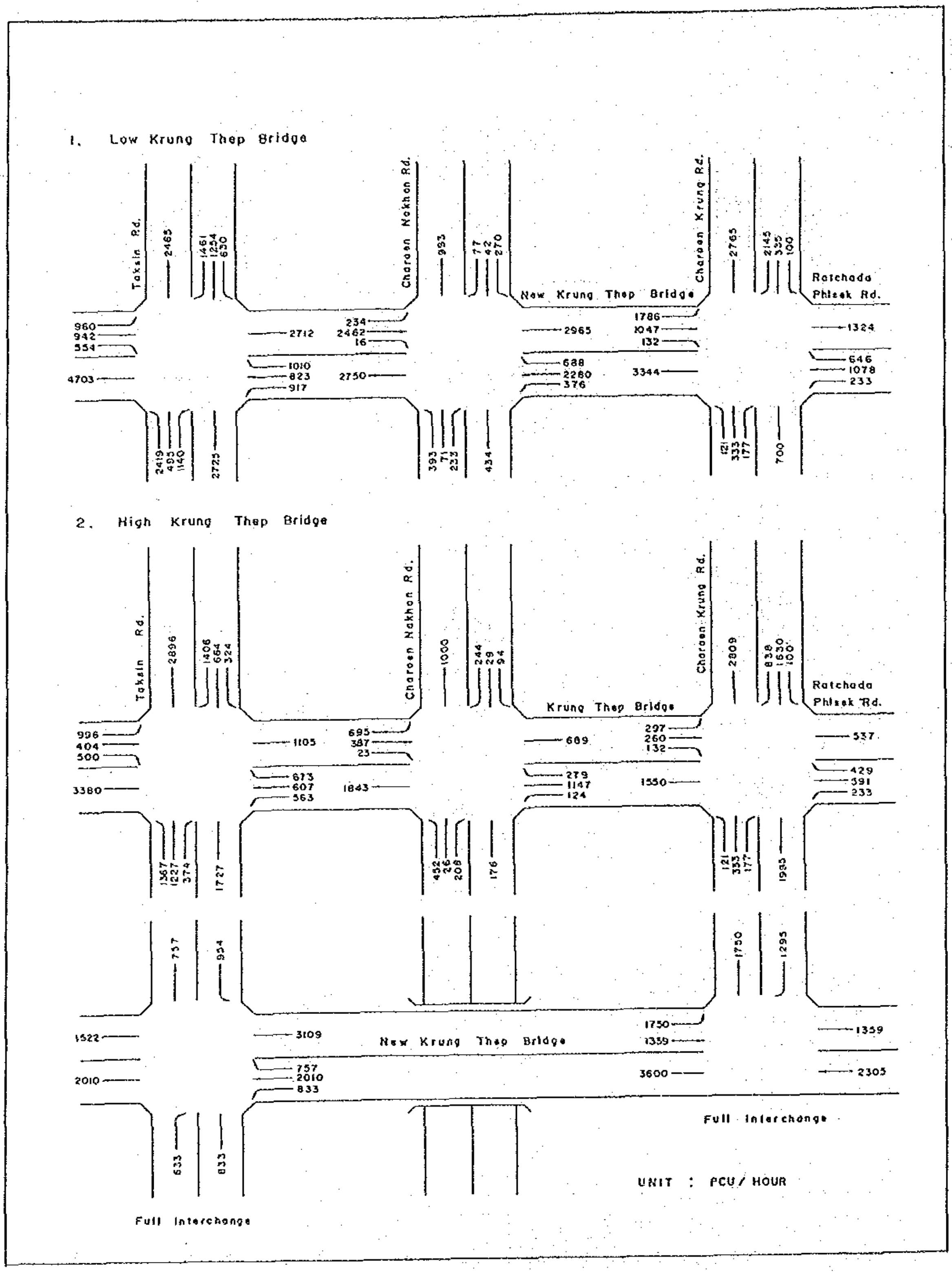

Fig. 8.3.2 Turning Movements in 2011 (Morning Peak)

In order to determine the future utilization of the existing bridge, a truck axle load study should be carried out based on actual data. The study team has obtained truck axle load data from the on-going study of trucking industry funded by IBRD.

These data are summarized in Table 8.3.2. Ten-wheel trucks carrying agricultural products were the heaviest in average weight (22.0 ton) and the maximum weight was found among 10 wheel trucks carrying mineral products (34.7 tons). Almost 70% of trucks exceeded 20 tons, the specified weight of TL-20 and HS-20. However, there was no truck as heavy as that specified in HB-45 unit.

Results of the roadside OD survey presented in Chapter 3 indicate that about one third of cargo carried around the Krungthep bridge were consumer goods, followed by agriculture/fishery products (22%), minerals (13%) and metal products (12%). Some 39% of those vehicles carrying cargoes were fully loaded.

It is likely that the gross weight of heavy trucks passing the existing Krungthep bridge often exceeds TL-20 or HS-20 standards, which the existing bridge can barely satisfy.

Therefore, it should be better that heavy trucks will not use the existing bridge. Truck movements around the Krungthep bridge were studied on the assumption that the existing bridge will be utilized with a limit on traffic loads and heavy trucks will be led to a new bridge through rampways.

All the alternatives can be classified into 3 types according to the accessibility from the three roads, i.e. Taksin Road, Charoen Nakhon Road and Chroen Krung Road. Basic conditions of the alternatives are as follow:

Type 1. (Plans D-2, E-3)

All heavy vehicles from/to existing cross roads will run through the at-grade intersections and rampways. Accessibility will be almost similar to the existing conditions.

Type 2. (Plans D-1, D-3, E-1, E-2)

All heavy vehicles from/to the Taksin Road an Charoen Krung Road will run through at-grade intersections and rampways. Heavy traffic from north of Charoen Nakhon Road will be smoothly led to the new bridge. However, heavy vehicles from the south of Charoen Nakhon Road will U-turn at the Middle Ring Road.

Type 3 . (Plan G-1)

Heavy vehicle traffic from/to the Taksin Road and Charoen Krung Road will be smoothly led to the new bridge through rampways. Heavy vehicles from/to the Charoen Nakhon Road will U-turn at the Middle Ring Road or take a detour.

Table 8.3.2 Truck Weight by Commodity

Commodity	Truck Type	No. of Sample	Average Weight (Tons)	Maximum Weight (Tons)	Percentage of Trucks Over 20 Tons
Agriculture/ Fishery	10 Wheel	44	22.0	32.3	50.0
	6 Wheel	5	12.6	15.6	0.0
Timber or Wood Products	10 Wheel	6	19.5	22.7	33.0
	6 Wheel	1	10.1	10.1	0.0
Mineral	10 Wheel	84	21.4	34.7	81.0
	6 Wheel	1	13.6	13.6	0.0
Consumer Good	10 Wheel	2	18.8	19.0	0.0
	6 Wheel	N.A.	-	-	-
Chemical Products	10 Wheel	3	19.2	19.8	0.0
	6 Wheel	N.A.	-	-	-
Total	10 Wheel	139	21.4	34.7	66.2
	6 Wheel	7	12.4	15.6	0.0

Table 8.3.3 Number of Lanes to be Required

Forecasted Year	Time Period	Type of Bridge	Traffic Volume To Bangkok	To Thonburi	Capacity	No. of Lane
2001	MP	Exist.	600	-	1,800	1
			-	700	1,800	1
		New	3,200	-	1,800	2
			-	2,800	1,800	2
						(Total 6)
2011	MP	Exist.	700	-	1,800	1
			-	1,600	1,800	1
		New	3,100	-	1,800	2
			-	3,600	1,800	2
						(Total 6)

In case of Type 1 and Type 2, many right turn movements of trucks are expected at the intersections. Such movements generally reduce the capacity of intersections. In case of Type 3, because of poor accessibility to the Charoen Nakhon Road, however, it should be expected that right turn movements will decrease at intersections. And it should also be expected that the traffic on the Charoen Nakhon Road and Krungthep Bridge will divert to other routes.

Truck movements around the Krungthep bridge were simulated using the traffic assignment procedure, based on the following conditions:

- OD table: Off peak truck OD year of 2011
- Network : Low New Krungthep Bridge with long Thonburi Road
  : High New Krungthep Bridge with long Thonburi Road

The results are shown in Fig. 8.3.3. All plans except G-1 were categorized into Low Krungthep bridge which was assumed to be the Type 2 case, because difference between Type 1 and 2 is negligible.

In case of the High Krungthep Bridge, total trucks using the Krungthep bridge would decrease only by 5% compared with the Low Krungthep bridge, however, it will have a poor accessibility to the Charoen Nakhon Road. The result of traffic assignment indicated no serious problem relating to the heavy vehicle traffic management, in High and Low Krungthep bridge cases.

3) Number of Lanes

Number of lanes was decided based on the comparison with lane capacity and forecast traffic volume.

The lane capacity was estimated as shown below:

* Existing, used as a 4-lane bridge ; 1,250 PCU/Hour
* Existing, used as a 2-lane bridge ; 1,800 "
* New Bridge ; 1,800 "

The number of lanes required is shown in Table 8.3.3.

4) Bridge Access Plans

a. Access Conditions

The relation between longitudinal gradient and vertical clearance for the three roads mentioned above was examined and is shown in Fig. 8.3.4.

Four cases of bridge profiles (case A through case D) were considered.

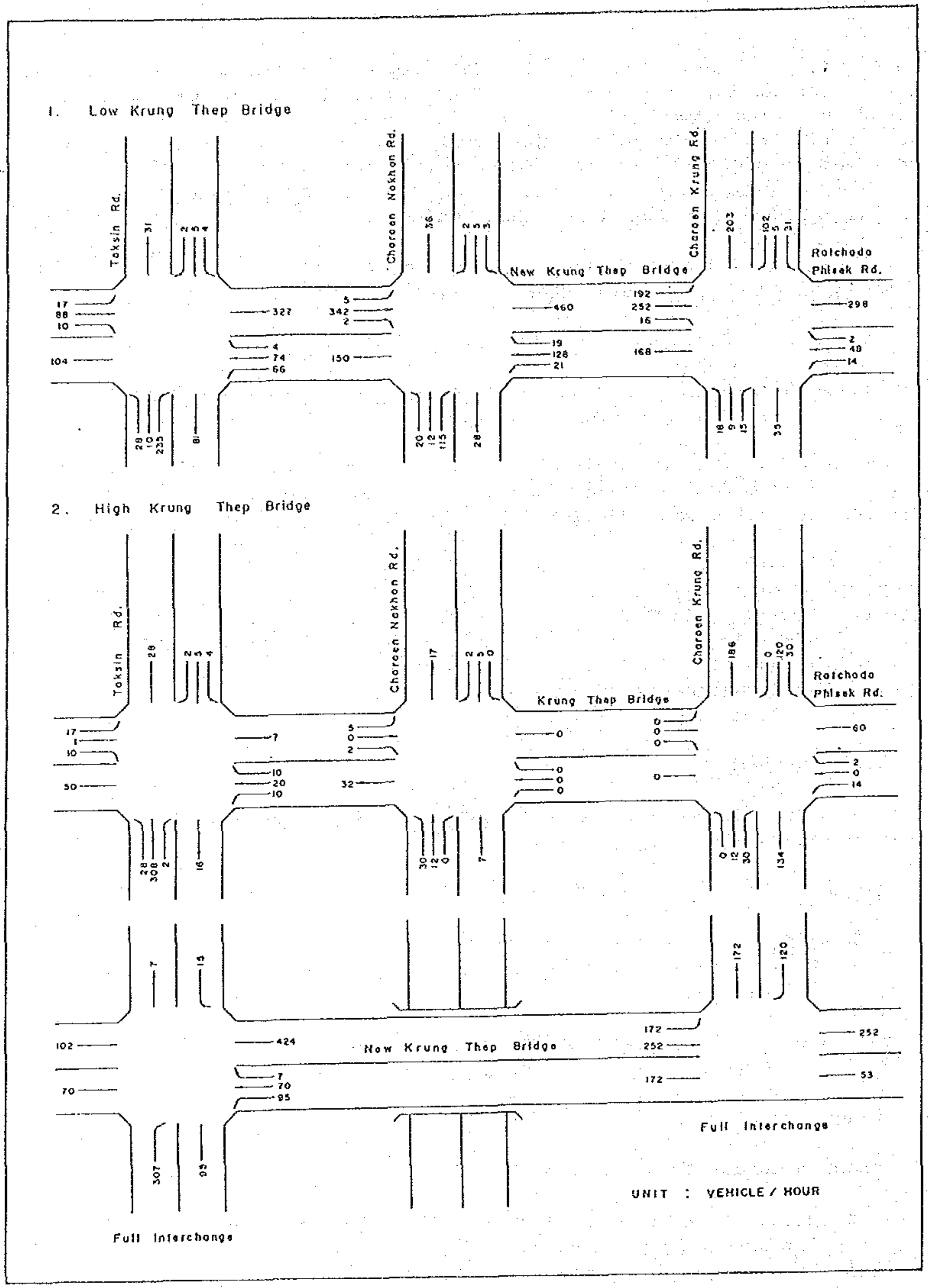

Fig. 8.3.3 Truck Turning Movements in 2011 (Off Peak)

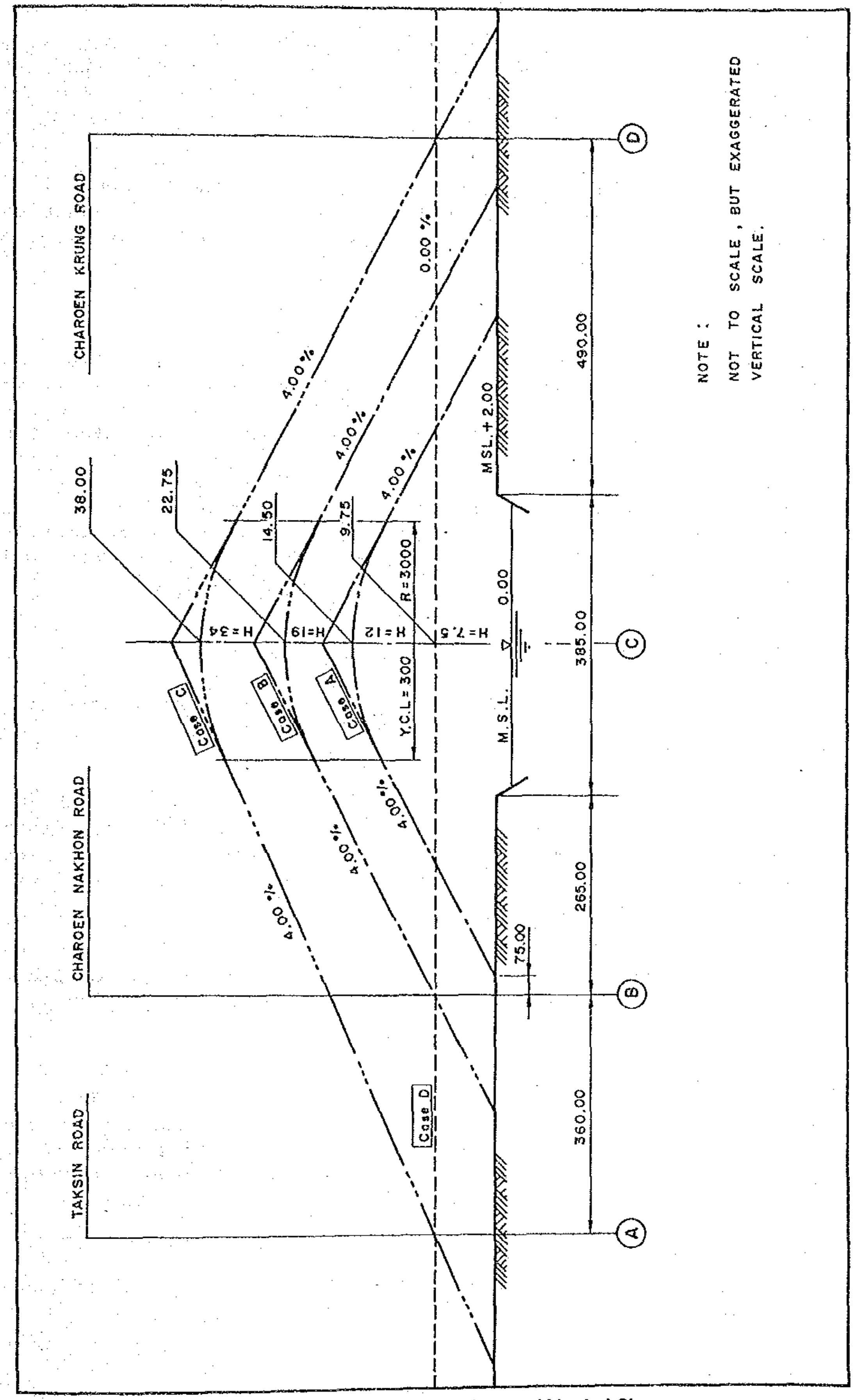

Fig. 8.3.4 Longitudinal Gradient and Vertical Clearance

The navigation clearance figures examined were 7.5 m, 12 m, 19 m and 34 m above MSL respectively. The low level bridge type that includes Alternative D and E follows the case D profile and the high level bridge type that means Alternative G follows the case C profile.

Case D can directly connect the abovementioned three intersections. However, in case C, it will be very difficult to connect at the B intersection due to the high vertical clearance.

b. Maximum Longitudinal Gradient

The maximum longitudinal gradient for through traffic lane was proposed at 4.0 per cent which is free from the critical climbing length of grade for the design speed of 80 km per hour as stipulated in the design standards of AASHTO and J.R.A. (See Foot Note)

The maximum longitudinal gradient for ON/OFF, Ramp was proposed at 7.0 percent considering the less construction cost and to shorter the length of ON/OFF ramp (L = 120 m). The details of geometric factors are discussed in Section 9.4 here in after.

8.3.2 Bridge Location

The location of an independent new bridge proposed in such plans as D-1, D-3, E-1, E-2 and G-1 was selected at the down stream side on the grounds of the following considerations:

1) According to the results of the bathymetric survey around the Krungthep bridge as described in Section 7.4, the foundation depth of the existing piers is minus 22 meters. Placing of a new pier adjacent and upstream may induce a dangerous scouring at the site of the existing pier.

   It was judged, therefore, that the upstream alignment of the new bridge is undesirable. The problem of scouring and other hydrological effects are discussed in more detail in Section 7.4, Hydrological Studies.

2) The Study Team's topographic survey results show that on Thonburi side two (2) Chinese shrines are located in the vicinity of the abutment of the bridge. One is situated on the upstream river front at a distance of 10 m from the existing bridge structure and the other on the downstream side about 18 m from the wall face of the approach road.

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*Note The critical climbing length to the grade for the 80 km per hour-road less or

4.0%	:	free
5.0%	:	600 m
6.0%	:	500 m
7.0%	:	400 m

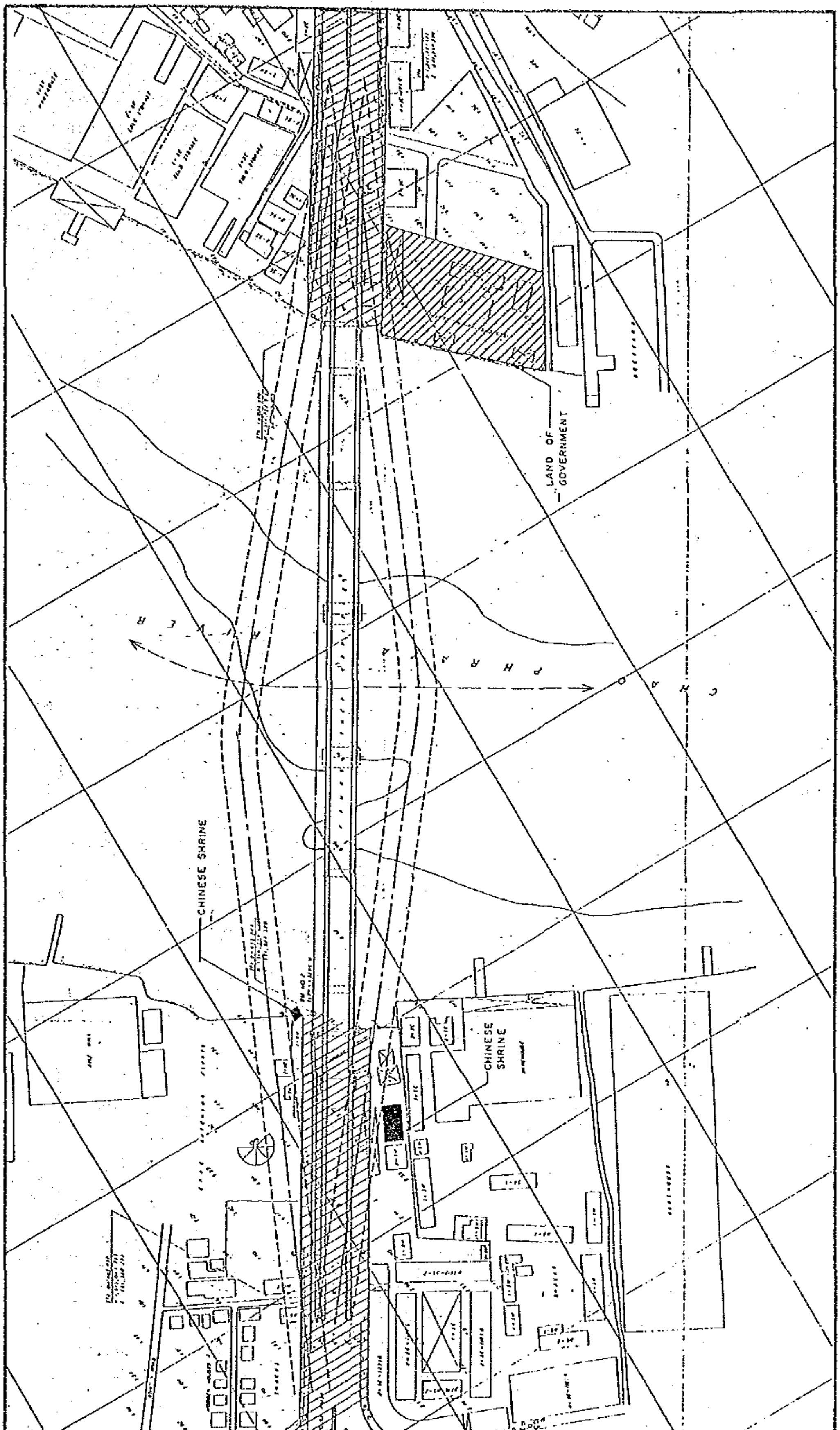

Fig. 8.3.5 Study on Bridge Location

Interviewed by the Study Team, the man who would take responsibility about the relocation of these shrines when required by the Government indicated a strong objection against such a relocation because of problems encountered after previous relocation requested by MOI.

These two (2) shrines are in the right of way of the New Krungthep Bridge. However, there would be flexibility to more the bridge site further downstream side to avoid the shrines.

3) On Bangkok side, the governmental office of "CUSTOMS TRAINING CENTER" is located on the downstream river front and this is a big advantage for land acquisition for the Project. The project would require only a part of its open yard.

Based on the above considerations, the location of a new bridge was determined to be on the downstream side. A reference figure is shown in Fig. 8.3.5.

8.3.3 Movable Bridge Mechanisms

Several types of movable bridge were considered. Some details are shown in Appendix 8.3.1.

8.4 Alternative Project Costs

Approximate project costs were estimated for each alternative taking into account various factors such as below:

- Standard cross sections of the new bridge;
- Construction method;
- Construction period;
- Land acquisition;
- Compensation for moving river facilities;
- Costs per unit area of facility;
- Costs for scouring protection;
- Costs of strengthening of the existing bridge; and
- Operating cost.

Various assumptions made for each of the above items are shown in Appendix 8.4.1.

Resulting approximate cost estimates for each alternative are summarized in Table 8.4.1.

Table 8.4.1 Approximate Cost Comparison

Unit: Million Bhat

Cost Items / Plans	Alternative D			Alternative E			Stage Wise Const.		Alternative G
	D-1	D-2	D-3	E-1	E-2	E-3	E-1	E-3	G-1
(1) Construction Cost	1,356	1,357	1,442	1,697	1,708	1,814	1,165	1,169	1,681
a. Main Bridge	245	253	178	463	442	543	463	544	437
b. Approach Bridge	472	479	533	471	498	479	172	126	469
c. Rampways	106	91	73	106	106	91	99	69	123
d. Access Road	30	30	30	30	30	30	-	-	30
e. Pavement Works	9	10	10	9	10	10	7	5	9
f. Strengthening of Existing Bridge	-	-	93	-	-	-	-	-	-
g. Micelaneous Works (30%)	259	259	275	324	326	346	222	223	321
h. Contingency (10%)	112	112	119	140	141	150	96	96	139
i. Engineering Services (10%)	123	123	131	154	155	165	106	106	153
(2) Second Stage Construction*	-	-	-	-	-	-	556	661	-
a. Construction Cost	-	-	-	-	-	-	506	601	-
b. Engineering Services (10%)	-	-	-	-	-	-	50	60	-
(3) Land Acquisition & Compensation	611	614	594	46	80	49	53	56	300
a. Land Acquisition	25	32	16	25	42	32	29	35	138
b. Building Compensation	21	17	13	21	38	17	24	21	162
c. River Facilities Compensation*	565	565	565	-	-	-	-	-	-
Total Project Cost	1,967	1,971	2,036	1,743	1,788	1,863	1,774	1,886	1,981

Note:

1. Other annual expense such as maintenance & operation cost of movable bridge, and economic loss while bridge is opened are taken into consideration in te economic evaluation.
2. After 10 years, the second stage is to be opened. The cost will be discounted in the economic evaluation.
3. Baht 500 Million from sale of the land of BKK Dock is not included.

8.5 Evaluation of Alternatives

8.5.1 Economic Evaluation

The method described in Section 4.6.1 was applied for each of the alternatives to obtain benefit amounts.

The process has been repeated for the three target years of 1991, 2001 and 2011 and benefit amounts for intermediate years were obtained by interpolation.

Preliminary costs as derived in Section 8.4 were in financial terms.

Factors converting the preliminary financial costs into economic costs were roughly estimated as follows:

E.S - Engineering Services

		Percentage to Construction Cost
Total engineering service cost	:	10%
Detail design service cost	:	3.5%
Construction supervision cost	:	6.5%

No conversion factor was assumed.

L.A - Land Acquisition Cost

No conversion factor was assumed.

C.C - Construction Cost

The economic cost of the concrete bridge project (D&G) was estimated at 90% (a conversion factor of 0.90), and that of the steel bridge project (E) was estimated at 85% (a conversion factor of 0.85)

M &
O.D - Maintenance & Operation Cost

No conversion factor was assumed

The residual value of the bridge and approach structures at the end of the 20-year period, i.e. year 2011, should be the initial construction cost less the amount needed to restore the whole to the initial conditions.* Eighty three per cent of the initial cost was assumed to be required at the end of the 20-year project period and was counted as a negative cost in the year 2011.

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* The total life of superstructure is normally considered to be 70 years whereas the substructure is considered to have an unlimited life. The replacement of the superstructure at the end of its life would cost 60% of the initial construction cost. Taking a straight line depreciation, the residual value at the end of the 20 year period was determined.

For each of the alternative plans a year-by-year cost stream including construction, maintenance and losses and a benefit stream for consumer surplus in generalized trip cost were established. Economic evaluation indicators such as the Benefit/Cost Ratio, the Net Present Value, both at a discount rate of 12%, and the Internal Rate of Return were calculated. Table 8.5.1 shows the resulting IRRs.

Table 8.5.1 IRR of Alternatives

Plan	IRR
D-1	18.60
D-2	18.58
D-3	18.35
E-1	21.22
E-2	20.83
E-3	20.57
E-2 Stage-wise	21.41
E-3 Stage-wise	21.41
G-1	18.84

8.5.2 Overall Evaluation and Conclusion

In order to determine the most recommendable plan, overall evaluation was made based on the evaluation criteria and weights shown in Table 8.5.2. The following explains each of the criteria used and associated scores (points) and evaluation weights.

1) Internal Rate of Return (IRR)

The internal rate of return of each plan was estimated as shown above. The plan E-1 staged construction yielded the highest rate of 21.4% and the plan D-3 showed the lowest rate of 18.4%. Scores were assigned in accordance with the classification shown in Table 8.5.2 IRR was considered to be the most important factor in selection of the best plan, therefore it was given 60% of the total weight. The following items in monetary terms were involved in calculating IRR:

- Project cost;
- Maintenance and Operation cost;
- Economic loss from disturbance to traffic;
- Project Benefits in VOC savings and time savings;
- Residual Value

2) Land Acquisition

The plans D-3 and E-3 can be realized with the least land acquisition of about 3,100 sq.m. On the other hand, the plan G-1 will require the largest land area of about 15,200 sq.m. However, the difficulty of land acquisition cannot be assessed by the area alone.

Table 8.5.2 Evaluation Criteria and Weights

Criteria	Scores 1	2	3	4	5	Weight
1. Internal Rate of Return	less than 8%	8 - 12%	12 - 0.18%	18 - 25%	over 25%	0.60
Plans Ranked				All plans		
2. Land Acquisition	Very difficult	Fairly difficult	A little difficult	No difficulty	Not required	0.06
Plans Ranked		D-2, E-3	D-1, D-3 E-1, G-1.	E-2		
3. River Facility, Moving (Bangkok Dock, Private)	Extremely difficult	Fairly difficult	Difficult	No need	No relations	0.10
Plans Ranked	All Plan D			G-1	All Plans E	
4. Navigation Safety	Impossible	Poor	Fair	Good	Excellent	0.08
Plans Ranked	All Plans D	E-2	E-3	E-1	G-1	
5. Risk Due to River Hydrology	Very High	High	Medium	Low	None	0.10
Plans Ranked		E-3	E-1, E-2.	All Plans D	G-1	
6. Motoring Public Image	Very Poor	Poor	Fair	Good	Excellent	0.03
Plans Ranked		All Plans E	G-1	D-1, D-2	D-3	
7. Appearance	Very Poor	Poor	Fair	Good	Excellent	0.03
Plans Ranked			E-3, G-1	D-1, D-2	D-3, E-2	

Each property has a particular value to its owner. A prime example is the two Chinese shrines.

All plans except the plans G-1 and E-2 will require relocation of one shrine on downstream side, and the plan D-2, E-3 will require relocation of both shrines.

Each plan was evaluated from the land acquisition based on the nature of the property to be acquired. The weight given to this criterion is 6% of the total considering the practical importance of land acquisition in the project implementation.

3) River Facilities Moving

In this evaluation only three categories are relevant: Very difficult, No need and No relation. The moving of governmental facilities such as Bangkok Dock and Marine Fisheries Division may be possible though difficult, but the moving of private facilities such as Harin Ship Building, B.L.L. Shipyard and Shaw Wanakit Co. seems to be extremely difficult as no legal means is available to the government, at least for the time being. Therefore, the facilities moving in the plans of Alternative D was evaluated to be very difficult, while, not be needed in the Alternative G and will have no relation in the Alternative E. Again, 10% of the total weight was assigned to this criterion considering its importance.

4) Navigation Safety

The Alternative D was formulated under the assumption to move the river facilities downstream, therefore its evaluation in terms of navigation safety was given the least score.

The plan E-2 cannot satisfy the requirement of the restricted channel length of 60 m, therefore it was evaluated to be poor, though not to be impossible. And plans E-3 and E-1 is evaluated to be fair and good, respectively. The weight given to this criterion was 8% of the total.

5) Risk Due to River Hydrology

The number and scale of newly constructed piers in the river are the key point to evaluate the effects of river hydrology, especially in the bend of the river.

The plan E-3 which requires the construction of 8 piers including large scale piers and separate 2-lane-bridges on both sides of the existing bridge, would pose a high risk. The plan G-1 which requires the construction of only 2 piers near each bank would have no problem of causing serious effects such as meandering or severe scouring. The plan D which requires the construction of slender piers was evaluated to cause low risk.

This evaluation was made considering not only the possibility of serious effects to the river but also the safety of structures in the curved river flow. The weight given to this criterion was 10% of the total.

6) Motoring Public Image

The following factors were considered in this evaluation:

- Traffic stoppage due to the bridge opening;
- Accessibility to the new bridge;
- At grade or grade separation intersection;
- Steepness of grade;
- Traffic management for truck movements; and
- Driving convenience, safety, and smoothness of running conditions.

The strengthened existing bridge of the plan D-3 with one-way system may be more appreciated by drivers than the economical interchanges in the plans D-1, D-2 and G which are serviced partly by grade separation and partly by signal management.

Forced stoppage while the movable bridge in plan E is open would certainly cause complaints from motorists. The weight given to this criterion was 3% of the total.

7) Appearance

Aesthetic appearance of the bridge is one of the important factors especially in Bangkok, where tourism is the major income generator. The weight given to this criterion was 3% of the total.

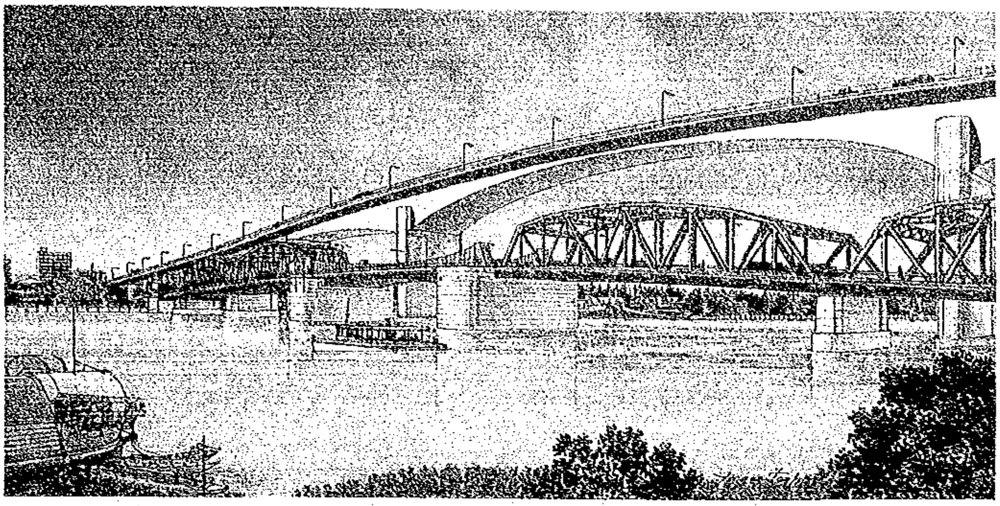
The artist views used for evaluation of the aethetic appearance of the bridges under the plans G-1 and E-2 are shown hereinafter.

8) Scoring Results and Conclusion

Table 8.5.3 summarizes the scoring results and the weighted total scores for each of the plans.

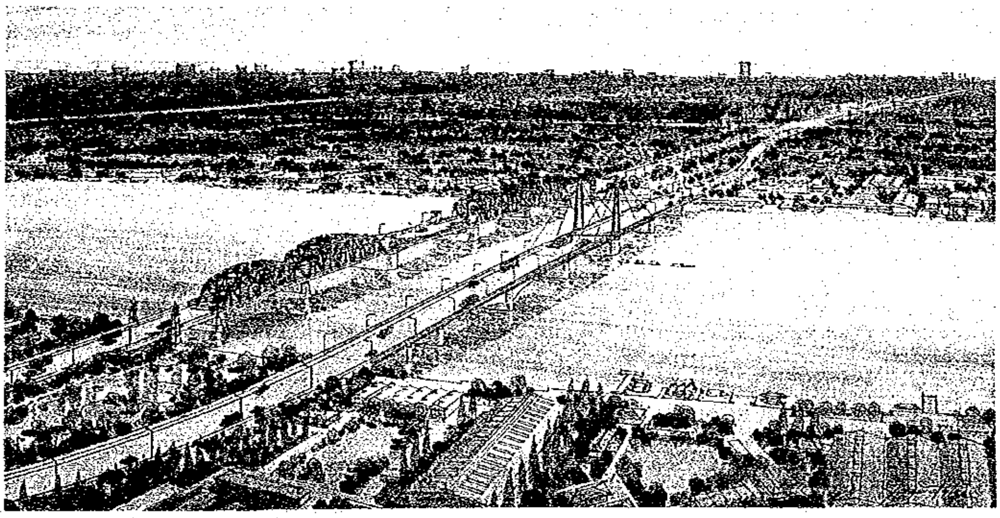
The Plan G-1 turned out to be the best considering all the factors described above.

PLAN G-1



Fixed Type Long Span PC Box Girder Bridge with High Pier
View from Upstream Side in Thonburi

PLAN E-2



Movable Type Short Span Cable Stayed Swing Bridge with Low Pier
View from Downstream Side in Thonburi

Table 8.5.3 Overall Evaluation by Weighted Score

Evaluation/Plans	Alternative D			Alternative E			Stage.	Con.	Alt. G	Score/Weight
	D-1	D-2	D-3	E-1	E-2	E-3	E-1	E-3	G-1	
1) Internal Rate of Return	4	4	4	4	4	4	4	4	4	1-5 / 60%
2) Land Acquisition	3	2	3	3	4	2	3	2	3	1-5 / 6%
3) River Facilities Moving	1	1	1	5	5	5	5	5	4	1-5 / 10%
4) Navigation Requirement	1	1	1	4	2	3	4	3	5	1-5 / 8%
5) Risk due to River Hydrology	4	4	4	3	3	2	3	2	5	1-5 / 10%
6) Motoring Public Image	4	4	5	2	2	2	2	2	3	1-5 / 3%
7) Appearance	4	4	5	4	5	3	4	3	3	1-5 / 3%
Total Weighted Scores	3.40	3.34	3.46	3.88	3.81	3.61	3.88	3.61	4.03	

1	G-1	4.03 points
2	E-1 (Stage-wise)	3.88 points
3	E-2	3.81 points
4	E-3 (Stage-wise)	3.61 points
5	D-3	3.40 points
6	D-1	3.40 points
7	D-2	3.34 points

CHAPTER 9

PROPOSED NEW KRUNGTHEP BRIDGE

9.1 Introduction

In the preceding discussions, it was determined that the vertical navigation clearance should be kept at 34 meters from MSL, and that the high long-span fixed bridge (Alternative G-1) was the recommended solution.

This chapter describes how a more detailed study was carried out by way of structural analysis to determine the types of structural elements and how a preliminary design was carried out for the proposed New Krungthep Bridge. Costing of the project and subsequent economic evaluation are also presented.

9.2 Design Criteria

Basic concepts for design standards of bridges are discussed below to establish design criteria for the study.

In recent years, highway bridge design in Thailand has generally followed AASHTO specifications, but some modifications have been made to meet local requirements arising from traffic conditions and natural conditions. As for live loads, HA and HB-45 unit loads have been adopted for the bridge design in Middle Ring Road and New Rama VI Bridge, reflecting the high proportion on overloaded trucks on Thai roads.

1) Navigation Clearance

Navigation vertical clearance of 34 meters is to be kept as proposed in Chapter 6.

2) Dead Load

The dead load consists of the weight of the completed structure, including the carriageway, curb, handrail and other public utility fittings.

For computation of the dead load the unit weights of materials are as specified in Article 1.2.2 of AASHTO standards.

As far as public utilities are concerned, installations of electric cables and telephone cables are scheduled as follows:

- Electric cables : 30 nos of 150 mm dia. pipe openings will be made.

- Telephone cable : 6 nos of 100 mm dia. pipe openings will be made.

The dead weights of the above items are negligibly small compared to others, and they are not considered in the Study.

3) Live Load

The live load consists of the weight of the applied moving load of vehicles, cars and pedestrians.

The load meets the HA and HB-45 unit loadings as specified in "6. Highway bridge live loads" of BSI BS5400, Part 2, 1978. Both loadings include impact, 25% of their total.

When side walks are provided, a live load of 0.4 tf/sq.m are considered for their design as specified in Section 3 of the "Standard Specification" for Highway Bridges, AASHTO-1983.

4) Longitudinal Forces and Centrifugal Forces

The longitudinal forces and centrifugal forces from live loads are as specified in the above mentioned BSI standards.

5) Wind Loads

Wind load forces are governed by the design wind velocity. The following design wind velocities have been adopted in the past or on-going projects in Bangkok.

	Design Wind Velocity	
- Sathorn Bridge	80 mph	(130 km/h)
- New Rama VI Bridge	100 mph	(160 km/h)
- Wat Sai Bridge	DIN Standards	(45 m/s)

When a high pier bridge is planned in an area where earthquake force is negligibly small, the wind load becomes often the dominant factor not only for superstructure design but also for substructure and foundation design. In this respect, a probability analysis was made by the Study Team (see Appendix 9.2.1) and a design wind velocity of 80 mph (130 km/h) was recommended for the 100-year return period.

Design wind velocity (New Krungthep Bridge) = 80 mph (130 km/h)

AASHTO base wind velocity = 100 mph (160 km/h)

The wind load intensity specified in AASHTO standards is decreased by the ratio of the square of the design wind velocity to that of the base wind velocity. The moving uniformly distributed wind load of the following intensities is accordingly applied horizontally.

For truss and arches	....	2,300 Pa	(235 kgf/sq.m)
For girders and beams	....	1,532 Pa	(160 kgf/sq.m)
For substructures	....	1,226 Pa	(125 kgf/sq.m)

6) Stream Current Force

Piers and other portions of structures which are subject to the force of flowing water must be designed to resist the following pressure specified in AASHTO standards:

$$P = 515\ K\ V^2$$

where, P = pressure (Pa)
V = maximum water velocity (m/s)
K = a constant, being 1.3/8 for square ends, 1/2 for angle ends (30 degrees or less), and 2/3 for circular piers.

A maximum water velocity of 2.0 m/s is applied.

7) Ship Collision Force

A static design force from ship collision is taken as the equivalent impact force that would be consequential from the collision of a 600 ton ship with the pile cap in the direction of flow of the river, and a half of this value in the cross stream direction. Ship collision forces have to be combined with stream current force.

8) Thermal Forces

The range of temperature for calculating stresses or movements resulting from variations in temperature is as follows:

Temperature rise	....	$10^{o}C$
Temperature fall	....	$20^{o}C$

9) Shrinkage and Creep

The effect from shrinkage and creep is calculated as given in Appendix C, Part 4, BSI. A mean relative humidity of 80% is adopted.

10) Earth Pressure

Structures which retain fills are proportioned to withstand earth pressure given by Rankine's formula.

11) Earthquake Force

An equivalent horizontal force of 0.05 W (which is considered as a dead load) is considered.

12) Materials

a. Concrete

The specified cylinder compressive strength of concrete at 28 days is as follows:

Prestressed Concrete, Precast:	fc = 400 kgf/sq.cm.
Prestressed Concrete, Cast-in-place:	fc = 350 kgf/sq.cm.
Reinforced Concrete, Superstructure:	fc = 250 kgf/sq.cm.
Reinforced Concrete, Substructure:	fc = 250 kgf/sq.cm.
Reinforced Concrete, Pile Cap:	fc = 250 kgf/sq.cm.
Cast-in-place Reinforced Concrete Pile:	fc = 250 kgf/sq.cm.
Precast PC Driven Pile:	fc = 350 kgf/sq.cm.

b. Structural Steel

Structural steel is anti-corrosive type material conforming to or equivalent to SMA41, SMA50 or SMA58 as specified in JIS G3114.

c. Steel Wire Cable

Steel wire cable is made of high strength steel conforming to or equivalent to RH62 to 82 as specified in JIS G 3506.

d. Reinforcing Bar

Ordinary reinforcement to be adopted is hot rolled high yield deformed bars conforming to SD40 as specified in TIS 24-2527 with a specified yield strength of 4,000 kgf/sq.cm. Some minor reinforcement for minor structures is hot rolled mild steel bars conforming to SR24 as specified in TIS 20-2527 with a specified yield strength of 2,400 kgf/sq.cm.

e. Prestressing Steel

Prestressing steel to be adopted is high strength normal relaxation 7-wir strands as specified in TIS 420-2525 with a specified ultimate strength of 18.9 tf/sq.cm.

9.3 Structure Type

The New Krungthep Bridge consists of the main bridge, approach span bridges and abutment structures. The main bridge is defined as the river crossing structure over the Chao Phraya River, and the approach span bridges are viaducts connecting the main bridge to Middle Ring Road. The maximum embankment height in the project area was estimated at about 6 meters. Therefore, the approach span bridges are to be planned to the points where the embankment height adjacent to abutments becomes 6 meters. For the rest, from the abutment to the end point of the embankment, some structures will be taken into consideration in order to withstand the embankment, otherwise the bottom width of the embankment (toe to toe) becomes wider and more land acquisition is needed.

The following subsections give particulars of the determination of the various type of structure.

9.3.1 Main Bridge

The main bridge span is planned just downstream of existing bridge, and pier arrangement in the river is planned to be in line with the existing piers to mitigate the hydraulic disadvantages. For this reason, the conceivable span length had to be either 70 meters or 220 meters. In case of 70 meters span length, the piers of the main bridge would be founded on the deepest portion of the riverbed caused by local scour resulting from the big projection of the existing bascule piers (refer to Section 7.4), and that construction of piers would be difficult and costly. Therefore, the main span of the bridge was determined at 220 meters in length.

When the main span length is 220 meters, the conceivable types of superstructures are steel Lohse girders (half through type), Gerber truss girders, steel cable-stayed girders, PC cantilever box girders and PC cable-stayed girders. Gerber truss girders have the disadvantage of requiring a very high girder depth resulting a higher deck level than the others. Therefore, Gerber truss girders were discarded in the subsequent comparison study.

In the subsequent study, the following four types of superstructure were examined and the most preferable was selected.

a) Steel Lohse girders
b) Steel cable-stayed girders
c) PC balanced cantilever box girders
d) PC cable-stayed girders

Prior to the determination of superstructure type, the most preferable type of pier foundation was studied and selected.

1) Selection of Preferable Type of Foundation

The pier foundations of main bridge are characterized by:

- The scour depth around the existing piers is estimated at about -30 m MSL.

- At a depth of -36 to -42 m MSL, there are dense to very dense sand layers with an SPT N-value of more than 30. This sand layer is considered unreliable because of the insufficient rooting depth of foundations once scour has occurred. Beneath the sand layer, hard silty clay lie at a depth of -40 to -52 m. This hard silty clay has an N-value of more than 30, but this layer is considered to be unreliable as the bearing stratum because the N-value dropped less then 25 in some places. Consequently, the recommend bearing stratum is the dense to very dense fine sand layer at the depth of -52 m MSL or below (refer to Fig. 7.2.2)

- The piers of the main bridge will be located in the riverbed, and off-shore construction will be required.

In this respect, the following foundation types were selected as the applicable alternatives, and they are depicted in Fig. 9.3.1.

a) Large diameter (2 m) cast-in-place reinforce concrete piles by reverse circulation drilling method (RCD)

b) Interlocked steel pipe well foundation

c) Open caisson

d) Pneumatic reinforced concrete caisson

A comparative study was made to clarify their advantages and disadvantages, and the results are summarized in Table 9.3.1.

As a result, the large diameter cast-in-place RC piles, having the advantages described below, were selected as the most preferable type of foundation for the main bridge.

<u>Advantages of large diameter cast-in-place RC pile</u>

- Already adopted and experienced in many bridge projects in Thailand.

- Suitable for the subsoil condition in the Chao Phraya River, which consists of sand and clay layers above the bearing stratum.

- All materials are available in the domestic market in Thailand.

- Relatively low construction cost and short construction period are required.

- Adaptable to the off-shore construction and ease of construction is expected.

2) Selection of Preferable Type of Superstructure

Four types of superstructure, i.e. a) steel Lohse, b) steel cable-stayed, c) balanced cantilever PC box and d) PC cable-stayed girders, were studied to obtain the most preferable solution among them. In this study, the use of 2 m diameter cast-in-place RC piles only was considered for pier foundations based on the preceding paragraphs.

A comparison was made to clarify advantages and disadvantages among the above four types of superstructure, such as in regard to contruction cost, construction method, construction period, availability of domestic materials, aethetics and others. The results of the comparative study are summarized in Fig. 9.3.2.

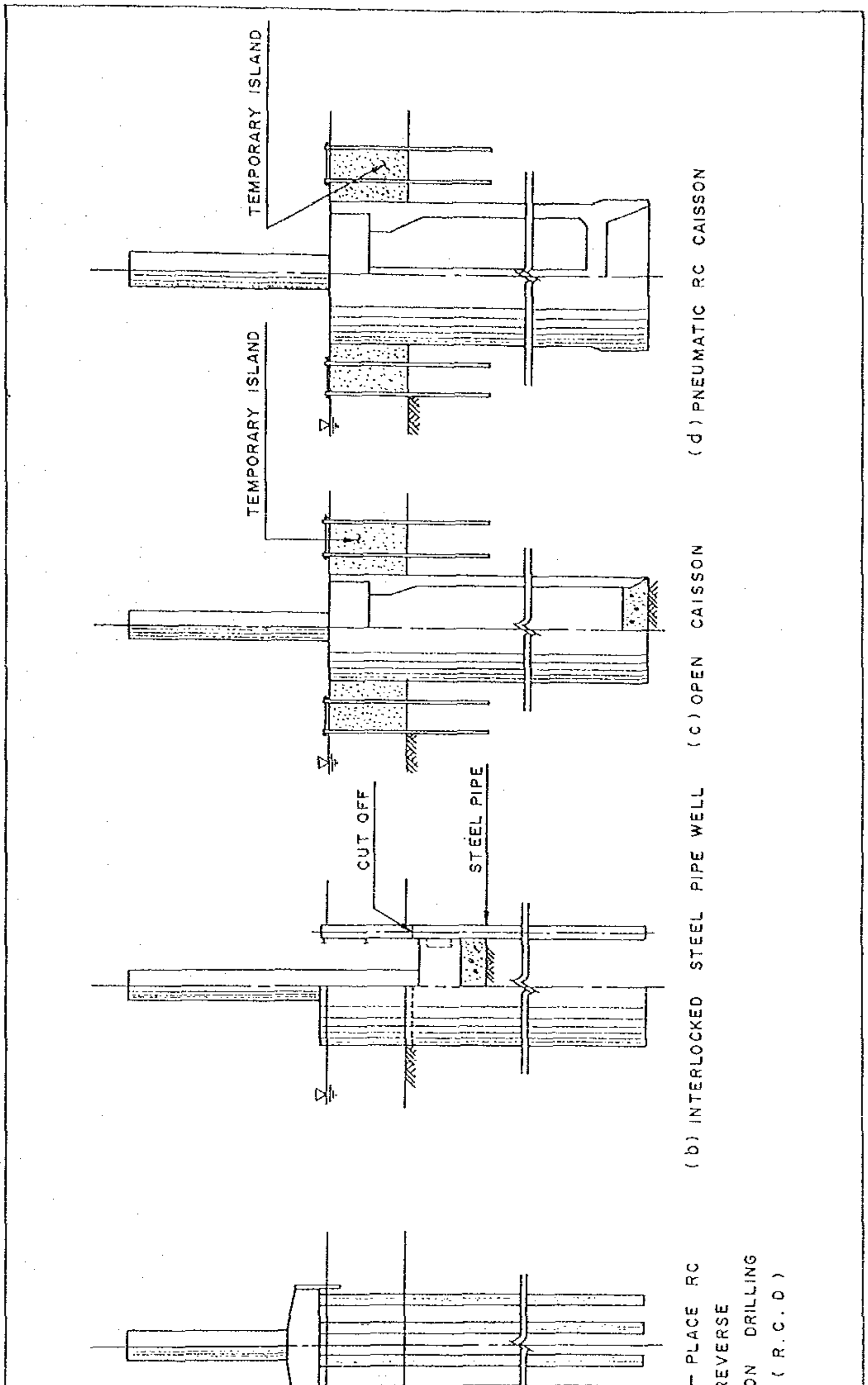


Fig. 9.3.1 Alternative Foundation Types

Table 9.3.1 Comparison of Foundation Types for Main Bridge

(Per one Pier)

	Large Diameter Cast-in-Place RC Piles(R.C.D. Piles)	Interlocked Steel Pipe Well	Open Caisson	Pneumatic Caisson
Principal Materials of Foundation	o Concrete in water o Reinforcing bar	o Steel pipe pile	o Concrete o Reinforcing bar	o Concrete o Reinforcing bar o Pneumatic facilities
Availability of Matrials from Domestic Market	Available	Not available	Availabale	Mostly available
Experience in Thailand	Many	Nil	Many	A few
Construction Periods Anticipated	Relatively short (9 months)	Short (7 months)	Relatively long (14 months)	Long (16 months)
Construction Costs Anticipated	38.8 million baht	62.0 million baht	35.2 million baht	46.4 million baht
Required Construction Technique	Protection of the bored hole surface	Accurate driving operation & high welding technique	Accurate sinking technique & correction of inclined caisson	Provision of high air pressure device
5ase of construction	Easy	Easy	Relatively difficult	Difficult due to civil works under high air pressure
Ease of Quality Control	Relatively difficult	Easy	Relatively difficult	Relatively difficult
Adoptability to Off-shore Construction	Easy	Easy	Relatively difficult	Relatiely difficult
Confirmation of Bearing stratum	Relatively easy	Relatively difficult	Relatively easy	Easy
Reliability of Supporting Capacity	Relatively reliable	Relatively reliable	Reliable	Reliable
Security against Close Construction	Relatively safe	Relatively safe	Relatively dangerous	Safe
Security against River Hydology	Safe	Safe	Relatively dangerous due to the obstacle island during construction	Relatively dangerous due to the obstacle island during construction
Durability against Corrosion	No problem	Less durable	No problem	No problem
Overall Evaluation	Recommendable	Not Recommendable	Not Recommendable	Not Recommendable

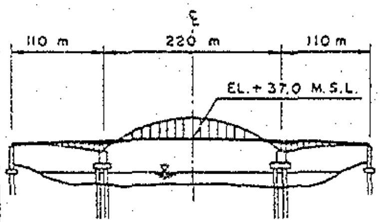
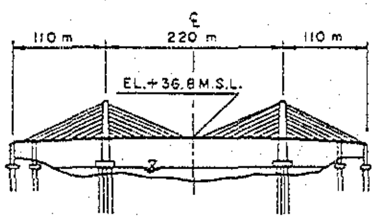
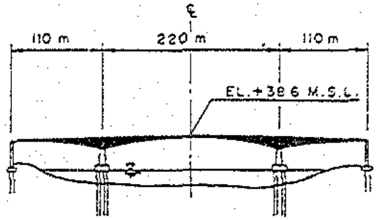
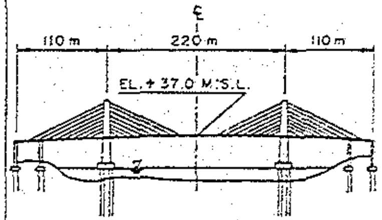
	a) STEEL LOHSE GIRDER	b) STEEL CABLE – STAYED GIRDER	c) BALANCED CANTILEVER PC BOX	d) PC CABLE – STAYED GIRDER
SIDE VIEW OUTLINE (NOT TO SCALE)	 GIRDER DEPTH = 2.6 ~ 4.8 m	 GIRDER DEPTH = 2.6 m	 GIRDER DEPTH = 3.5 ~ 14.0 m	 GIRDER DEPTH = 2.6 m
PRINCIPAL MATERIALS OF SUPERSTRUCTURE	○ ANTI – CORROSIVE STRUCTURAL STEEL	○ ANTI – CORROSIVE STRUCTURAL STEEL ○ STEEL WIRE CABLE	○ CONCRETE ○ REINFORCING BAR ○ P.C. TENDON	○ CONCRETE ○ REINFORCING BAR ○ P.C. TENDON ○ STEEL WIRE CABLE
AVAILABILITY OF MATERIALS FROM DOMESTIC MARKET	NOT AVAILABLE	NOT AVAILABLE	MOSTLY AVAILABLE	MOSTLY AVAILABLE
CONSTRUCTION METHOD AND CONSTRUCTION ASPECT	CABLE ERECTION METHOD	CANTILEVER ERECTION METHOD	CANTILEVER ERECTION METHOD USING CAST – IN – PLACE CONCRETE	CANTILEVER ERECTION METHOD USING PRECAST PC SEGMENTS
CONSTRUCTION PERIODS ANTICIPATED	26 MONTHS	30 MONTHS	36 MONTHS	36 MONTHS
CONSTRUCTION COST – SUPERSTRUCTURE	347 MILLION BAHT	236 MILLION BAHT	275 MILLION BAHT	230 MILLION BAHT
CONSTRUCTION COST – SUBSTRUCTURE AND FOUNDATION	130 MILLION BAHT	195 MILLION BAHT (Including Tower)	185 MILLION BAHT	262 MILLION BAHT (Including Tower)
CONSTRUCTION COST – TOTAL	477 MILLION BAHT	431 MILLION BAHT	460 MILLION BAHT	492 MILLION BAHT
CONSTRUCTION COST – COST PER SQUARE METERS	57,400 BAHT / m^2	51,800 BAHT / m^2	55,300 BAHT / m^2	59,200 BAHT / m^2
AETHETICS	FAIR	GOOD	FAIR	GOOD
FUTURE MAINTENANCE ASPECT	ANTI – CORROSIVE MEASURE IS REQUIRED.	ANTI – CORROSIVE MEASURE IS REQUIRED.	ALMOST MAINTENANCE FREE	ANTI – CORROSIVE MEASURE IS REQUIRED FOR CABLES
OVERALL EVALUATION	NOT RECOMMENDABLE	ALTERNATIVE	RECOMMENDATION	NOT RECOMMENDABLE

Fig. 9.3.2 Comparison of Superstructure by Type

The construction costs in Fig. 9.3.2 exclude the common items such as pavement, curbs, handrails, ancillary works and others. These costs were estimated based on the prevailing prices in Bangkok (Arelatively low unit price was adopted for structural steel, which was nearly equivalent to the actual bid price in a recent bridge project in Bangkok).

By this comparative study, c) Balanced Cantilever PC Box Girder was judged to be recommendable for the following reasons:

- The total construction cost of the balanced cantilever PC box girders is thought to be the least cost solution. Even when the relatively low unit price of structural steel is applied to the steel bridges, the cost of steel cable-stayed girders cannot improve upon the balanced cantilever PC box girders by more than 10%. In short, it can be conservatively said that the construction cost of balanced cantilever box girders will provide the cost-minimum solution to feasibility level accuracy.

- The balanced cantilever PC box girders can be constructed mostly by using domestic materials available in Thailand.

- This type has been adopted and experienced in many recent projects in Thailand, and it can be expected that the necessary manpower and equipment will be easily available during the construction stage.

- Costly future maintenance like painting work for a steel type bridge will not be required in the future.

- Steel type bridges are not free from maintenance even for anti-corrosive structural steel or zinc coated steel (hot dip galvanized steel). The magnitude of maintenance costs is judged to be still larger than that of PC bridges due to the inevitable rust and corrosion in some limited parts which were observed on 70% of anti-corrosive steel bridges in U.S.A. (Reported by the American Iron & Steel Institute in 1980).

Although the balanced cantilever PC box girders were judged as the JICA recommendation in the Study, the steel cable-stayed girder was consider as a possible alternate to the recommendation. The reasons for proposing such an alternative are the following:

- As world market prices of steel products have been at a standstill since the second oil shock (1979), steel type bridges were bid many times at less than 50% of the Engineer's estimates. Such bidding was observed in Thailand as well.

- When the low unit price of structural steel, nearly equivalent to the actual bid price in a recent bridge project in Bangkok, was applied to the steel bridges a) and b), the total construction cost of b) steel cable-stayed girders was found to be the lowest cost of the four.