6.3.3 Cost Estimate

(1) Basic Condition

Following basic conditions are applied for the construction cost estimate for the 5-type bridges.

- Unit rates of labour, materials and equipment in the year of 1995 are obtained from JKR and interview surveys were made to some local contractors. The unit rates are in and around Kuala Lumpur, and the local deviation of the rates are not considered in the estimate.

- Indirect cost such as preliminaries and contractor's overhead and profit are calculated using the multiplier factors.

- Production rate in the unit cost analysis is based on standard production rates of various work items in Japan after some modification is made in consideration of Malaysian local conditions.

(2) Structure of Project Cost

The total project cost consists of construction cost, administration engineering cost and land acquisition/compensation cost, and contingency. The construction cost is divided into direct cost and indirect cost. The direct cost is further subdivided into labour, material and equipment cost and the indirect cost is subdivided into general cost, preliminary cost and contractor's overhead and profit.

Structure of total project cost is shown in Fig.6.8. Construction cost for the 5-type of standard bridges is estimated in this Study, and the main items of construction cost are briefly described below.

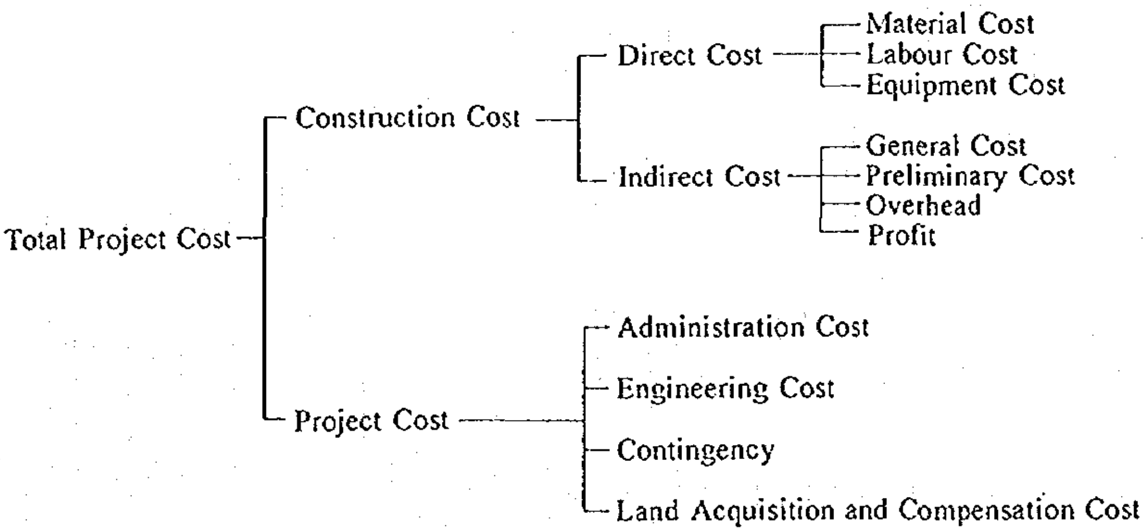

Fig. 6.8 Structure of Total Project Cost

(a) Labour Cost

Labour cost includes wages, income tax, insurance and all fringe benefits, such as vacation, sick leave, medical and workmen's compensation.

(b) Material Cost

Cost of materials and manufacturing products in the year of 1995 is estimated on the basis of data obtained from market investigation.

(c) Equipment Cost

The cost of construction equipment is estimated on the basis of market investigation. It is considered that the equipment expense per unit per hour includes depreciation cost, operator's wages, cost of maintenance, fuel and lubricants necessary for equipment operation and repair.

(d) General Cost

General costs are as follows:

- Construction of temporary bridge and road
- Demolition of existing bridge
- Relocation of existing public utilities
- Temporary diversion of river/waterway

(e) Preliminary Cost

Preliminary cost includes, mobilization/demobilization, site office/ laboratory, warehouse, electricity/water supply, transportation, engineering and etc., and it is assumed as 10 to 20% of the direct cost.

(f) Overhead and Profit

The overhead including job overhead and general overhead, and profit are assumed as 20 to 30% of the direct cost.

(3) Unit Cost

To determine the time required to perform a given quantity of work, it is necessary to estimate the probable rates of production of the labour and equipment. It is, however, difficult to estimate the accurate production rate due to lack of records and data in Malaysia.

Therefore, the production rate being used in Japan is modified taking into account labour's skillfulness, efficiency of equipment, operator's capability in Malaysia as well as based on those in similar projects in ASEAN countries.

Finally, the unit cost of each work item is calculated using the calibrated production rate.

(4) The 5-Type Bridges

The typical 5-type bridges for cost estimation are selected as follows:

Type of Bridge	Span length (m)	Height of Abutment (m)	Height of Pier (m)
1. RC solid slab (RCSS)	10	6	-
2. Pre-tensioned solid slab (PRSS)	10	6	-
3. Pre-tensioned hollow slab (PRHS)	16	6	10
4. Pre-tensioned composite T-beam (PRT)	22	6	10
5. Post-tensioned composite T-beam (PTT)	28	6	10

Note: The width of above bridges is 13.9 m.
Calculated quantities of each bridges are summarized in Table 6.4 and Table 6.5.

(5) Condition of Cost Estimate

Construction costs are estimated under the following conditions.

- The construction site is located from Kuala Lumpur within 100km.
- The structure excavation for substructure is carried out by open excavation without temporary diversion of river/waterway.
- Prestressed spun concrete piles (dia 600m/m) are driven by pre-auger method.
- Ready-mixed concrete is available.
- Post-tensioned beams are fabricated on approach road or on river bed.
- Pre-tensioned beams and post-tensioned beams are handled and launched by truck crane.
- Electricity and water are available on site.
- Cost of service diversions, demolition of existing structures, temporary bridge/road and land acquisition are not included.
- Preliminary cost is assumed at 15% of the direct cost.
- Contractor's overhead and profit is assumed at 25% of the direct cost.

(6) Cost Estimate

Construction costs of single span of the 5-type bridges are summerized in Table 6.6. Construction costs of each bridge are shown in Table 6.7 - Table 6.13.

Table.6.4 Quantity of Superstructure

Items	Unit	PRSS-10m		PRHS-16m		PRT-22m		PTT-28m	
		Per beam	Per span	Per beam	Per span	Per beam	Per span	Per beam	Per span
Precast PC beam									
Concrete (grade 50)	cu.m	4.42	79.6	5.90	106.25	11.43	125.69	24.84	173.90
Reinforcing steel	ton	0.262	4.72	0.365	6.575	1.118	12.29	2.071	14.497
Prestressing steel	ton	0.138	2.484	0.274	4.939	0.501	5.514	1.059	7.410
Duct	lin.m	-	-	-	-	-	-	113.8	796.8
Form	sq.m	22.1	-	38.6	-	81.2	-	135.3	-
Cross beam									
Concrete (grade 50)	cu.m	-	12.26	-	24.47	-	14.33	-	20.14
Reinforcing steel	ton	-	-	-	-	-	0.628	-	1.095
Prestressing steel	ton	-	0.717	-	1.554	-	0.462	-	0.354
Duct	lin.m	-	162.7	-	352.6	-	104.8	-	65.2
Form	sq.m	-	13.0	-	19.9	-	75.2	-	103.2
RC slab									
Concrete (grade 40)	cu.m	-	-	-	-	-	63.11	-	79.79
Reinforcing steel	ton	-	-	-	-	-	12.192	-	15.498
Form (RC plate)	sq.m	-	-	-	-	-	123.7	-	206.2
Weight of PC beam	ton	11.1		14.8		28.6		62.1	

RCSS – 10m

Concrete (grade40)	: 194 cu.m
Reinforcing steel	: 1.601 ton
Formwork	: 34 sq.m
Falsework	: 24 cu.m

Table.6.5 Quantity of Substructure

Items	Unit	Abutment (H = 6m)				Pier (H = 10m)		
		RCSS-10m PRSS-10m	PRHS-16m	PRT-22m	PTT-28m	PRHS-16m	PRT-22m	PTT-28m
Concrete (grade 40)	cu.m	130.1	129.5	134.7	127.8	188.9	197.9	215.9
Reinforcing steel	ton	6.505	6.475	6.735	6.390	11.334	11.874	12.954
Form	sq.m	184.3	185.1	185.0	184.0	273.1	273.1	279.1
Leveling con (t = 10cm)	cu.m	4.5	4.5	4.5	4.5	4.3	4.8	5.7
Cobble stone (t = 20cm)	cu.m	9.0	9.0	9.0	9.0	8.6	9.6	11.4
PC Pile (600mm x 30m)	nos	18	18	18	18	18	20	24
Excavation (assumed)	cu.m	554	554	554	554	547	564	629
Backfill (assumed)	cu.m	477	477	477	477	439	447	494
Falsework	cu.m	-	-	-	-	23	23	23

Table 6.6 Construction Cost of Single Span Bridge

(M$)

Type of Bridge	Superstructure	Abutment	Total
1. RC Solid Slab (RCSS - 10m)	115,880	442,730	558,610
2. Pre-Tensioned Solid Slab (PRSS - 10m)	162,610	442,730	605,340
3. Pre-Tensioned Hollow Slab (PRHS - 16m)	266,160	442,510	708,670
4. Pre-Tensioned T-beam (PRT - 22m)	370,240	446,490	816,730
5. Post-Tensioned T-beam (PTT - 28m)	480,060	441,080	921,140

Table 6.7 Construction Cost of Superstructure
(RC Solid Slab, RCSS - 10m)

Work Item	Unit	Rate (M$)	Qty	Amount (M$)
Concrete (grade 40)	cu.m	194	107.8	20,913
Reinforcing steel	ton	1,601	14.84	23,759
Formwork	sq.m	34	177.3	6,028
Falsework	cu.m	24	429	10,296
Bearing (Elastomeric bearing)	No.	750	10	7,500
Sub-total				68,496
Parapet and handrail	lin.m	250	21	5,250
Drainage	L.S	120	1	120
Expansion joint (Dummy joint)	lin.m	80	26	2,080
Pavement	sq.m	50	136.5	6,825
Sub-total				14,275
Preliminaries at 15%				12,416
Overhead and profit at 25%				20,693
Total Construction Cost				115,880
Unit Construction Cost				
per sq.m of bridge deck				794

Table 6.8 Construction Cost of Superstructure
(Pre-tensioned Concrete Solid Slab, PRSS - 10m)

Work Item		Unit	Rate (M$)	Qty	Amount (M$)
Manufacturing PC beam		No.	3780	18	68,040
Transportation		No.	555	18	9,990
Handling and launching		No.	445	18	8,010
Cross beam,	Concrete (grade 50)	cu.m	240	12.3	2,952
	Reinforcement	ton	-	-	-
	Formwork	sq.m	40	13.0	520
	PC cable	No.	888	12	10,656
RC slab,	Concrete (grade 40)	cu.m	-	-	-
	Reinforcement	ton	-	-	-
	Formwork	sq.m	-	-	-
Bearing (Elastomeric bearing)		No.	250	36	9,000
Sub-total					109,168
Parapet and handrail		lin.m	250	21	5,250
Drainage		L.S	120	1	120
Expansion joint (Dummy joint)		lin.m	80	26	2,080
Pavement		sq.m	50	136.5	6,825
Sub-total					14,275
Preliminaries at 15%					8,310
Overhead and profit at 25%					30,861
Total Construction Cost					162,614
Unit Construction Cost per sq.m of bridge deck					1,114

Preliminaries = (109,168 - 68,040 + 14,275) x 15%

Table 6.9 Construction Cost of Superstructure
(Pre-tensioned Concrete Hollow Slab, PRHS - 16m)

Work Item		Unit	Rate (M$)	Qty	Amount (M$)
Manufacturing PC beam		No.	6,290	18	113,220
Transportation		No.	740	18	13,320
Handling and launching		No.	715	18	12,870
Cross beam,	Concrete (grade 50)	cu.m	240	24.5	5,880
	Reinforcement	ton	-	-	-
	Formwork	sq.m	40	19.9	796
	PC cable	No.	888	24	21,312
RC slab,	Concrete (grade 40)	cu.m	-	-	-
	Reinforcement	ton	-	-	-
	Formwork	sq.m	-	-	-
Bearing (Elastomeric bearing)		No.	375	36	13,500
Sub-total					180,898
Parapet and handrail		lin.m	250	33.2	8,300
Drainage		L.S	180	1	180
Expansion joint (Dummy joint)		lin.m	80	26	2,080
Pavement		sq.m	50	215.8	10,790
Sub-total					21,350
Preliminaries at 15%					13,354
Overhead and profit at 25%					50,562
Total Construction Cost					266,164
Unit Construction Cost					1,154
per sq.m of bridge deck					

Preliminaries = (180,898 - 113,220 + 21,350) x 15%

Table 6.10 Construction Cost of Superstructure
(Pre-tensioned Concrete Composite T-beam, PRT - 22m)

Work Item		Unit	Rate (M$)	Qty	Amount (M$)
Manufacturing PC beam		No.	12,870	11	141,570
Transportation		No.	1,430	11	15,730
Handling and launching		No.	1,710	11	18,810
Cross beam,	Concrete (grade 50)	cu.m	240	14.3	3,432
	Reinforcement	ton	1,800	0.63	1,134
	Formwork	sq.m	40	75.2	3,008
	PC cable	No.	888	8	7,104
RC slab,	Concrete (grade 40)	cu.m	194	63.1	12,241
	Reinforcement	ton	1,601	12.19	19,516
	Formwork	sq.m	50	123.7	6,185
Bearing (Elastomeric bearing)		No.	525	22	11,550
Sub-total					240,280
Parapet and handrail		lin.m	250	45.4	11,350
Drainage		L.S	240	1	240
Expansion joint (Plug type joint)		lin.m	500	26	13,000
Pavement		sq.m	50	295.1	14,755
Sub-total					39,345
Preliminaries at 15%					20,708
Overhead and profit at 25%					69,906
Total Construction Cost					370,239
Unit Construction Cost					1,173
per sq.m of bridge deck					

Preliminaries = (240,280 - 141,570 + 39,345) x 15%

Table 6.11 Construction Cost of Superstructure
(Post-tensioned Concrete Composite T-beam, PTT - 28m)

Work Item		Unit	Rate (M$)	Qty	Amount (M$)
Manufacturing PC beam		No.	26,500	7	185,500
Transportation		No.	-	-	-
Handling and launching		No.	5,000	7	35,000
Cross beam,	Concrete (grade 50)	cu.m	240	20.1	4,824
	Reinforcement	ton	1,800	1.10	1,980
	Formwork	sq.m	40	103.2	4,128
	PC cable	No.	888	5	4,440
RC slab,	Concrete (grade 40)	cu.m	194	79.8	15,800
	Reinforcement	ton	1,601	15.50	24,816
	Formwork	sq.m	50	206.2	10,310
Bearing (Elastomeric bearing)		No.	700	14	9,800
Sub-total					296,598
Parapet and handrail		lin.m	250	57.4	14,350
Drainage		L.S	300	1	300
Expansion joint (Plug type joint)		lin.m	500	26	13,000
Pavement		sq.m	50	373.1	18,655
Sub-total					46,305
Preliminaries at 15%					51,435
Overhead and profit at 25%					85,726
Total Construction Cost					480,064
Unit Construction Cost					1,203
per sq.m of bridge deck					

Table 6.12 Construction Cost of Abutment (H = 6m) per one unit

Work Item	Unit	Rate (M$)	RCSS - 10m PRSS - 10m		PRHS - 16m		PRT - 22m		PTT - 28m	
			Qty	Amount (M$)	Qty	Amount (M$)	Qty	Amount (M$)	Qty	Amount (M$)
Excavation	cu.m	10	554	5,540	554	5,540	554	5,540	554	5,540
Backfill	cu.m	12	477	5,724	477	5,724	477	5,724	477	5,724
Levelling concrete (t = 10cm)	cu.m	120	4.5	540	4.5	540	4.5	540	4.5	540
Cobble stone (t = 20cm)	cu.m	37	9.0	333	9.0	333	9.0	333	9.0	333
PC spun pile (600mm x 30m)	No.	5,784	18	104,112	18	104,112	18	104,112	18	104,112
Concrete (grade 40)	cu.m	194	130.1	25,239	129.5	25,123	134.7	26,132	127.8	24,793
Reinforcing steel	ton	1,601	6.51	10,423	6.48	10,374	6.74	10,791	6.39	10,230
Formwork	sq.m	34	184.3	6,266	185.1	6,293	185.0	6,290	184.0	6,256
Sub-total				158,117		158,039		159,462		157,528
Preliminaries at 15%				23,718		23,706		23,919		23,629
Overhead and profit at 25%				39,529		39,510		39,866		39,382
Total Construction Cost				221,364		221,255		223,247		220,539

Table 6.13 Construction Cost of Pier (H = 10m) per one unit

Work Item	Unit	Rate (M$)	PRHS - 16m		PRT - 22m		PTT - 28m	
			Qty	Amount (M$)	Qty	Amount (M$)	Qty	Amount (M$)
Excavation	cu.m	10	547	5,470	564	5,640	629	6,290
Backfill	cu.m	12	439	5,268	447	5,364	494	5,928
Levelling concrete (t = 10cm)	cu.m	120	4.3	516	4.8	576	5.7	684
Cobble stone (t = 20cm)	cu.m	37	8.6	318	9.6	355	11.4	422
PC spun pile (600mm x 30m)	No.	5,784	18	104,112	20	115,680	24	138,816
Concrete (grade 40)	cu.m	194	188.9	36,647	197.9	38,393	215.9	41,885
Reinforcing steel	ton	1,601	11.33	18,139	11.87	19,004	12.95	20,733
Formwork	sq.m	34	273.1	9,285	273.1	9,285	279.1	9,489
Falsework	cu.m	24	23	552	23	552	23	552
Sub-total				180,307		194,849		224,799
Preliminaries at 15%				27,046		29,227		33,720
Overhead and profit at 25%				45,077		48,712		56,200
Total Construction Cost				252,430		272,788		314,719

6.4 Preparation of Manual

6.4.1 General

Manuals were prepared at the final stage of the Study and intended to serve as a guide for the usage of the standard design by JKR engineers. The preparation have started to map out the plan and contents of the manual as follows.

The standard design applied to highway bridges on federal road built by RC or PC beams with spans less than 45m. Within this scope, the manual sets forth minimum requirements for the application of the standard design, which are in the main parts consistent with the current British Standards and their practices. The manual aims for the basic understanding of the design of standard type bridges on federal roads.

The manual consists of the following 5 divisions.

- Division I for bridge planning
- Division II for bridge structural analysis
- Division III for bridge construction plan and cost-estimate
- Division IV for operation of design programme
- Division V for operation of drawing programme
- Division VI for operation of quantity calculation
- Division VII for operation of substructure design

6.4.2 Preparation of Manual

Manual covers all fundamentals needed for the JKR engineers to carry out the bridge design work from planning up to cost estimate. Each of the divisions can be used independently of the other but are actually inter-related with each other in the process of design work.

Division I discusses briefly the basic technical procedures needed for planning of bridges by utilizing the standard design. It includes necessary topographic and geological surveys, highway and waterway requirements, principles for bridge structural layout and basic type selection, and construction method and cost saving considerations. It does not discuss about approach road embankment which has to be done on an individual basis.

Division II of the manual covers the bridge structural analysis system developed in the Study. It explains the outlines of the analysis system, design standards adopted, computer programmes used in the system, how to decide input data and how to judge output data. It does not iterate the theories and formulas used in the system which are based mostly on the British standards. However, some interpretations are presented on ambiguous points of the standards and their applications.

Division III is meant to be used as a first reference for the JKR engineers in preparing construction plan and cost estimate, and it also will help the process of bridge planning in connection to Division I. It explains the basic technical information generally representing the current practices and problems of the short to medium span concrete bridge construction in Malaysia. However, it includes neither the general construction specifications for materials and workmanship nor the administration for contract.

Division IV is the operation manual for computer-aided design programme developed in the Study. It explains the outlines of the programme system and how to operate the system using the copies of the actual computer displays. It also attached the input data lists for standard design in the Study as the reference to the future design work by JKR engineers.

Division V is the operation manual for computer-aided drawing programme developed in the Study. Similar to the Division IV, it explains the programme system, method of operation and also attached the input data lists for standard drawings in the Study.

Division VI is the operation manual for quantity calculation programme for superstructure developed in the Study. It explains the outline, contents and method of operation.

Division VII is the operation manual for substructure design programme developed in the Study. It explains the programme system, method of operation and sequence of operation displays.

CHAPTER 7 CONCLUSION AND RECOMMENDATION

7.1 General

The conclusion and recommendation in this chapter were prepared after review and evaluation of all major study results through each phase of the Study. An assessment of the Study was also presented as a part of the conclusion.

7.2 Conclusion

7.2.1 Necessity of the Standardization of Bridge Design

In the Malaysian national transport system, road transport is by far the most popular mode of transportation for both passenger and freight. Traffic studies in 1991 have shown that 99.8% of passengers and 98.5% of freight traffic were transported by road. It is foreseen that in the coming decade, the role of road network will indeed become even more important and prominent as the main mode of transport of goods and passengers.

Up to date, a total of about 45,000km of roads has been built in the country and among those, the federal roads amounted to 16,000km.

On the road network, bridges are key elements because of their strategic locations and of the adverse consequences when they fail or when their capacity is impaired. It is estimated that there are about 4,500 bridges in Malaysia, out of which 2,500 bridges are located on federal roads.

In an effort to further improve the efficiency of the transport industry, the *Government undertook the Phase 1 of the National Axle Load Study (1986 – 1988)*. This Study showed that the limitation on the loading capacity of bridges emerged as the major constraint in allowing heavier permissible truck load. As a spin off from the National Axle Load Study, the Government also received technical assistance from JICA (1992) in a study called the Bridge Rehabilitation and Maintenance Study. The Study results revealed the various deficiencies in the studied bridges which includes the deficiencies due to improper bridge design and construction.

These deficiencies should be eliminated in new bridge design and construction, for efficient implementation and maximum utilization of the limited available resources. In order to achieve the objectives, establishment of standard design of appropriate types of superstructures and typical design of some types of substructure at an early stage is a basic need to GOM.

7.2.2 Major Results in Engineering Aspect

(1) Basic Design Standard

The basic design standards adopted in this Study are based on the British

Standard's "Limit State Design Method" to meet the request of GOM and because of their wide practicality in Malaysia.

They are Bridge Design Standard: BS 5400, Design Load Standard: BD37/88, Foundation Design Standard: BS 8004, and JKR Geometric Design of Roads. However, the Japanese Standards were also adopted whenever the above standards are not applicable.

(2) Superstructure

Practically five different types of superstructure were developed for various span length, including 3-span continuous type. The standard bridges were designed to cater for a skew angle of up to 30 degrees.

Type	Span Range (m)
Reinforced concrete solid slab	5 to 10
Pre-tensioned concrete solid slab	5 to 10
Pre-tensioned concrete hollow slab	10 to 16
Pre-tensioned concrete T-beam	18 to 22
Post-tensioned concrete T-beam	22 to 45

(3) Substructure

All the abutments and piers are furnished with the footings to be embedded sufficiently under river bed to provide more durable and stable structures from a view point of river hydrology.

(a) Bridge Abutments

Inverted T-abutment was adopted as a typical design. The height of the abutment ranges from 6m to 12m high and will support the superstructure for the various span range as stated above. It can cater for a skew angle of up to 30 degrees.

(b) Bridge Piers

Two types of piers were adopted and these include T-type pier and multiple column pier. The height varies from 10m to 20m and will support the various span range of superstructures as stated above.

(c) Sample Design

Some sample design, besides the typical types mentioned above, were carried out by the request made by JKR and these include:-

- 8 meters high T-abutment on spread foundation
- 12 meters high T-abutment (railway bridges)

- 30 meters high T-pier with 3 types of foundation
- Multiple column pier on bored pile foundation

(4) Foundation

Since the majority of JKR bridges are across rivers, the foundation are usually founded on piles. In view of this, the Study concentrates mainly on the design of pile foundation. However, an example on the design of spread foundation was carried out.

In the Study, two types of pile were considered for the bridge foundation: driven pile (PC pile) and bored pile. Design calculation examples to determine the design load on piles based on friction and end-bearing were compiled in the design manuals for references. However, since ground condition varies from one location to another, the designer must carry out the geotechnical designs to determine the soil carrying capacity and subsequently the depth of piles.

(5) Selection and Development of Computer Aided Design & Drawing

The computer system, hardware and software, was selected for personal computer system in consideration of the capacity for computerized design system, popularity in Malaysia, easiness in use, reasonable cost and compatibility with IBM-PC which is most common in Malaysia.

The software, on the other hand, for the design system used for this Study was exclusively developed by the Study Team. The automatic design programme was built for the design of standard bridges and it was also developed as the simple dialogue personal computer system for easiness in operation by bridge engineers in Malaysia. An automatic drawing system and a comprehensive computer programme were developed mainly for superstructure. It is closely linked with the design analysis programme, covering all the standard structure types and also equipped for the quantity estimation. However, no specific automatic drawing programme for substructure was prepared. Utilizing the existing auto-CAD in JKR, all the necessary drawing data of the typical substructure types are manually input to produce drawings for standard case, which allows engineers to draughting for other cases in accordance the standard case.

7.2.3 Consideration Paid in Selection of the Standard Bridge Types

Several parameters were considered in the Study to determine the suitable types of bridges to be adopted:

(1) Materials

The construction materials, eg. cement, steel bars and prestressing strands, adopted in the standard bridge design are those which are widely available locally. Nevertheless, these materials must meet the minimum requirement specified in the Codes.

(2) Economic

Economic comparison were carried out between the proposed prestressed beam and the beam that are currently used in bridge construction.

(3) Method of Construction

In developing the standard bridges, the Study Team has adopted current methods of construction that are available locally. Any new method of construction being proposed are deemed to be viable and practical.

(4) Maintenance

The standard bridges were selected to take into account of the maintenance aspect. Various good design practice in minimizing future maintenance problems are incorporates in the standard bridge design, and these are as follows:-

- Beams with straight edges
- Effective scouring protection
- Ensure durability by using higher concrete strength, sufficient cover, crack width control
- Quality control of local contractors
- Proper layout of the bridge

(5) Production of Precast Members

The precast prestressed structural members were developed after taken account of the technical and production capability of the local manufacturers. Simple sectional beam shape with straight edges were adopted in the Study to ensure high quality finished products. In selecting the precast beams, the Study Team has also try to reduce initial investment cost of a new bedding by the manufacturers.

(6) Aesthetic Consideration

The aesthetic of the standard was considered whenever possible in the form of simplicity and symmetry of shape and slimness of the overall bridge structures.

7.2.4 Technology Transfer and Training

Apart from the preparation of a design manual, it was one of main objectives of the Study to train and transfer technology to the engineers of the Bridge Unit, JKR.

To achieve the objectives, the Study Team carried out the design and draughting works in Malaysia for the period of 6 months. GOM provided 6 extra JKR personnels to the Study Team to undergo an on-the-job training, thus the objective was achieved in the form of understanding the computations and operation of the computer programme. Their contribution is much appreciated.

7.2.5 Assessment of the Bridge Design Standardization

With the introduction of the standard bridges, the following benefits are anticipated:

- Deficiencies, such as an overdesign or an underdesign encountered due to individual design of case to case, will be eliminated, and a more systematic, rational and economical, as a whole, bridge design could be achieved.

- The design will efficiently deal with the increase of live load due to heavier vehicle traffic and also loading characteristics of special vehicles like trailer.

- A more systematic maintenance works could be practiced by the standardization of bridge types.

- The State and the District JKR will be able to carry out the bridge design for short span bridges quickly by utilizing the standard drawings, and also they are able to improve the knowledges of bridge engineering by the prepared design manual, which covers planning, design, construction and cost estimate.

7.3 Recommendation

7.3.1 In Practical Use of the Standard Design

(1) The standard bridge types adopted would not require a radical change of existing facilities in production of PC beams by the local manufacturers. Therefore, they should be put into practical use as early as possible with a minimum transitional period for modification of the existing facilities.

(2) It should be understood that the bridge design standardization was prepared for the aim of overall efficiency and economy in design, construction and maintenance of the short span bridges, therefore, it has certain limitations and a careful examination should be made in application of the standard designs to a specific, individual site condition.

(3) The Bridge Unit, JKR should have the authority to examine and to approve all the bridge design and appropriateness in application of the standard designs under JKR jurisdiction.

7.3.2 Necessity of Improvement in Planning Bridges

The visual inspection of existing bridges revealed the need of improvement as in the following:-

- a sufficient opening under bridge should be kept.
- skewed bridges should be avoided as much as possible in connection with road alignment and river conditions.
- a sufficient revetment should be provided and maintained properly to protect bridge structures.

Besides of the above, all necessary guidelines for proper bridge planning were explained in the design manual.

7.3.3 Design of Superstructure and Substructure

(1) Superstructure

For the design of prestressed concrete members under Serviceability Limit State (SLS), the limitation of tensile stress (Class 1 under load combination 1) was applied. However, in consideration of the occurrence of the load specified in BD37/88 is extremely seldom and of the characteristics of restoration of prestressed concrete member, the limitation of tensile stress should be relaxed in the design. If so, a more rational and economical design of prestressed concrete members could be achieved.

(2) Substructure

A partially computerized and manual input system was adopted for the design of substructure and foundation. Considering the burdens encountered in the process and a rapid increase of demand of the design, a fully computerized system and programme should be developed for the design of substructure and foundation at an early stage.

7.3.4 Institutional Arrangement

(1) The inspection and the supervision forces on bridge construction sites should be strengthened more at the District and the State level.

A strict specification and a good design themselves do not guarantee a quality controlled finished product without proper inspection and supervision.

(2) There are quite number of skilled and experienced draughtmen who are capable to operate auto-CAD at the Bridge Unit, JKR. If, some simple and easy education on the basic rules and requirements of the design is implemented, their quality will sure be graded up more and careless mistakes in draughting could be prevented.

APPENDICES

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APPENDIX A

MINUTES OF MEETINGS ON THE INCEPTION REPORT

MINUTES OF MEETING

ON THE INCEPTION REPORT FOR

THE STUDY ON

THE STANDARDIZATION OF BRIDGE DESIGN

IN

MALAYSIA

AGREED UPON BETWEEN

PUBLIC WORKS DEPARTMENT

ON BEHALF OF

THE GOVERNMENT OF MALAYSIA

AND

JAPAN INTERNATIONAL COOPERATION AGENCY

KUALA LUMPUR, 25th AUGUST 1994

DATO' IR CHUA SOON POH
DIRECTOR OF ROADS BRANCH
PUBLIC WORKS DEPARTMENT
ON BEHALF OF
THE GOVERNMENT OF MALAYSIA

MR. ISAMU HISADA
TEAM LEADER
STUDY TEAM
ON BEHALF OF
JAPAN INTERNATIONAL
COOPERATION AGENCY

Witness

MR. SEE AH SING
ASSISTANT DIRECTOR OF INFRASTRUCTURE
ECONOMIC PLANNING UNIT
ON BEHALF OF
THE GOVERNMENT OF MALAYSIA

Witness

MR. KAZUHIRO NISHIKAWA
CHAIRMAN
ADVISORY COMMITTEE
ON BEHALF OF
JAPAN INTERNATIONAL
COOPERATION AGENCY

JICA Study Team submitted the Inception Report of the Study on the Standardization of Bridge Design in Malaysia to the Public Works Department (JKR) on 19th August 1994. Joint meetings between the Malaysian and the Japanese sides were held from 24th August 1994 to 25th August 1994 for the presentation and discussion on the Inception Report.

Technical Committee and Steering Committee meetings were held on the 24th August 1994. The Malaysian and the Japanese sides discussed and confirmed on the following subjects:

1. Submission of the Inception Report
   The Study Team submitted 50 copies of the Inception Reports to JKR. JKR acknowledged the receipt of the Reports and agreed to the contents therein in principle.

2. Design Method to be Adopted
   The Malaysian side again requested to adopt the "Limit State Design Method". The Malaysian and the Japanese sides agreed that the structural analysis for the Standard Bridges shall basically be carried out according to the British Standard "Limit State Design Method" , but the Japanese "Allowable Stress Design Method" will be considered whenever the British Standard is not applicable.
   (reference: Clause III. (2) of the Scope of Work dated 26th January 1994)

3. Bridge Live Load
   The Malaysian and the Japanese sides agreed that the bridge live load to be adopted in the design shall be in accordance with BD 37/88.
   (reference: Clause 2. (b) of the Minutes of Meeting dated 26th January 1994)

4. Design for the Substructures
   In addition to the contents of Clause 7. (b) of the Minutes of Meeting dated

26th January 1994, the Malaysian and the Japanese sides also agreed that for the substructures, a partially computerised design programme shall be developed. Design samples and manual shall be prepared and the drawings shall be prepared by CAD (manual).

5. Request from the Malaysian side:

The Japanese side agreed to convey the request of the Malaysian side that provision be made during the course of the Study for:

a) One Malaysian counterpart to undergo training in Japan for the fiscal year 1994.

b) Two Malaysian counterparts to undergo a 3 months on-the-job training in Japan on the design of bridges for the fiscal year 1995.

Appendix 1

LIST OF ATTENDANCE

Malaysian Side:

1.	Dato' Ir. Chua Soon Poh	Director, Roads Branch
2.	Ir. Rohani Abdul Razak	Assistant Director (Bridge)
3.	Mr. Amir Ismail	Engineer (Bridge)
4.	Mr. Zainudin Jasmani	Engineer (Bridge)

JICA Advisory Committee:

1.	Mr. Kazuhiro Nishikawa	Chairman, Advisory Committee
2.	Mr. Yasuo Inokuma	Member, Advisory Committee

JICA Coordinator:

1.	Mr. Yuji Ikeda	Staff, JICA Headquarters

JICA Malaysia Office:

1.	Mr. Yuzo Yamamoto	Staff, JICA Malaysia Office

Study Team:

1.	Mr. Isamu Hisada	Leader, Study Team
2.	Mr. Hajime Sakai	Member, Study Team
3.	Mr. Hiroshi Honda	Member, Study Team
4.	Mr. Takashi Chujo	Member, Study Team
5.	Mr. Takashi Furukawa	Member, Study Team
6.	Mr. Hideaki Takaura	Member, Study Team
7.	Mr. Kazuo Kataoka	Assistant

APPENDIX B

LIST OF DATA COLLECTED

APPENDIX B : A LIST OF DATA COLLECTED

CATEGORY	TITLE OF DATA	PUBLISHER	REFERENCE NO.
General	Malaysia Handbook 1992	Chamber of Japanese	
Socio Economic	Year Book of Stasistics 1992	Dept of Statistics, Malaysia	
Traffic	Malaysia Road General Information 1994	JKR	
Costing	417/1, 421/3 Lane 5, Jalan Banting, Klang	JKR	
	Unit Price for Building Works		
	A Sample of Unit Price for Civil Works	-	
	Consumer Price Index - September 1994	Dept of Statistics, Malaysia	ISSN: 0127-9491
	Special Release 1 (For Civil Engineering Works) September 1994	Dept of Statistics, Malaysia	ISSN: 0127-8568
	Special Release 2 (For Building Works) September 1994	Dept of Statistics, Malaysia	ISSN: 0127-8576
Design Standard	A Guide to Design of Bridges	JKR	
	Standard Drawings of Bridges	JKR	
	Depatmental Standard BD 37/88 Loads for Highway	Department of Transport, UK	
	Proposed Amendment to BD 37/88 Appendix A Clause 6.8 and 7.7	Department of Transport, UK	
	JKR Specification for Bridge Live Load	JKR	
	Standard Specification for Road Works	JKR	
	A Guide on Geometric Design of Roads	JKR	
	Guidelines for Processing of Application and of Terms and Conditions for Bridge and Sewerage, 1994	DID (Translated by JICA Study Team)	
Hydrology	Anual Summary of Meteorogical Observations, 1992	Malaysian Meteorogical Services	ISSN 0126-8864
River Planning	Planning and Design Procedure No.1:Urban Drainage Design Standard and Procedures for Peninsular Malaysia	DID	
	Hydrological Procedure No.1: Estimation of the Design Rainstorm in Peninsular Malaysia, 1982	DID	
	Hydrological Procedure No.4:Magunitude and Frequency of Floods in Peninsular Malaysia, 1987	DID	
	Hydrological Procedure No.5:Relation Method of Flood Estimation for Rural Catchments in Peninsular Malaysia, 1989	DID	
	Hydrological Procedure No.11:Design Flood Hydrograph for Rural Catchments in Peninsular Malaysia, 1987	DID	
	Hydrological Procedure No.18:Hydrological Design of Agricultural Drainage systems, 1977	DID	
Geological	Annual Report - Geological Survey of Malaysia 1992	Ministry of Primary Industries	ISSN 0127-0559
	The Quaternary Deposits in the Coastal Plains of Peninsular Malaysia	Geological Survey Headquarters	QG/1 of 1988
	Geological Map of Sarawak	G. Survey, Sarawak 1992	201/92

	Geological Map of Sarawak - Relative Reliability	National Mapping of M'sia	
	Geological Map of Sabah	G.Survey of M'sia 1985	
	Geological Map of Selangor	National Mapping of M'sia	
	Geological Map of Selangor	G. Survey of M'sia	73-76
	Geological Map of P.Pinang, Seberang Prai & K. Kurau	National Mapping M'sia 1992	200-92
	Geological Map of Peninsular Malaysia	G. Survey of M'sia	
	Geological Map of Peninsular Malaysia	National Mapping M'sia	KBM(rm)A-16-85
	Geological Map of Batu Pahat Area, Johor		
	Geological Map of Muar Area, Johor		
Tender Document	Specification for the changing of bridges no. 414/9, 417/1, 421/3 Lane 5, Jalan Banting, Klang	JKR	
	Unit Price for Building Works	JKR	
Map	Peninsular Malaysia	National Mapping, M'sia 1993	L4010/6PPNM
	Peninsular Malaysia-Kedah	National Mapping, M'sia	
	Peninsular Malaysia-N. Sembilan, Johor	National Mapping, M'sia	
	Sabah & Wilayah Persekutuan, Labuan	National Mapping, M'sia 1988	1307/2-PPNM
	Sarawak	National Mapping, M'sia 1988	1307/2-PPNM
	State of N. Sembilan Road Map	National Mapping, M'sia	189/88
	State of Pahang Road Map	National Mapping, M'sia	62/89
	State of Johor Road Map	National Mapping, M'sia	60/89
	State of Penang Road Map	National Mapping, M'sia	75/88
	State of Melaka Road Map	National Mapping, M'sia	190/88
	State of Kelantan Road Map	National Mapping, M'sia	64/89
	State of Kedah Road Map	National Mapping, M'sia	61/89
	State of Perlis Road Map	National Mapping, M'sia	188/88
	State of Trengganu Road Map	National Mapping, M'sia	63/89
	State of Perak Road Map	National Mapping, M'sia	131/89
	Peninsular Malaysia Road Map	National Mapping, M'sia 1993	2001/1-PPNM
Programing	Computer Engineering Applications	CEANET	
Substructure	Pile Design and Construction Practice - Fourth Edition	E & FN Spon	

APPENDIX C

COMPARISON OF DESIGN LOADING

COMPARISON OF DESIGN LOADING

1. **Live Load**

(1) **BS 5400**

(a) HA loading

- Nominal uniformly distributed load (UDL)

$$W = 151\ (1/L)^{0.475} \text{ but less than } 9$$

where, W = load per metre of lane (in kN)

L = loaded length (in m)

- Nominal knife edge load (KEL)

The KEL per notional lane shall be taken as 120 kN.

(b) HB loading

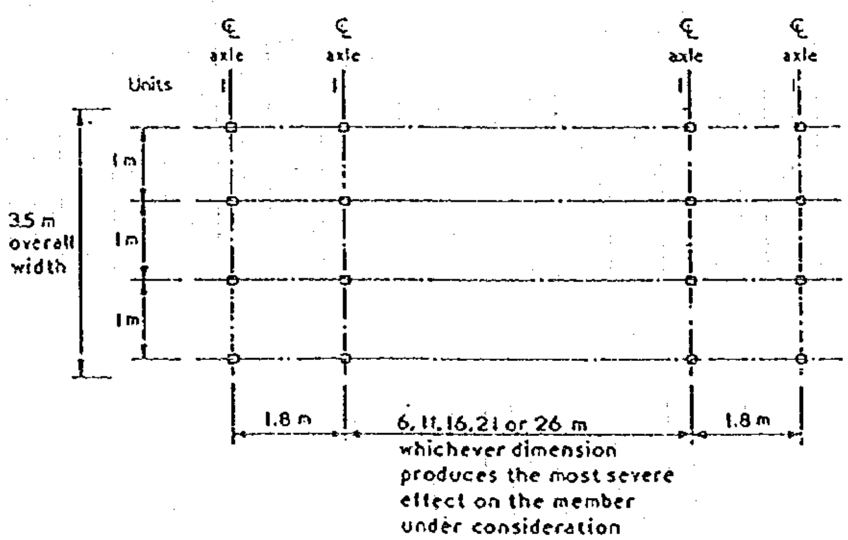


Fig. C.1 Dimensions of HB Vehicles

where, one unit shall be taken as equal to 10 kN axle (i.e. 2.5 kN per wheel). The minimum number of units shall normally be considered is 25.

(2) **LTAL and SV loading in accordance with JKR specification**

(a) LTAL loading

- Nominal uniformly distributed load (UDL)

$= 176.8\ (1/L)^{0.6}$ $L <= 20m$

$= (93.6 + 4.16L)\ (1/L)^{0.6}$ $20m <= L <= 40m$

$= 260\ (1/L)^{0.6}$ $40m <= L <= 50m$

where W = load per metre of lane (in kN)

L = loaded length (in m)

(b) SV loading

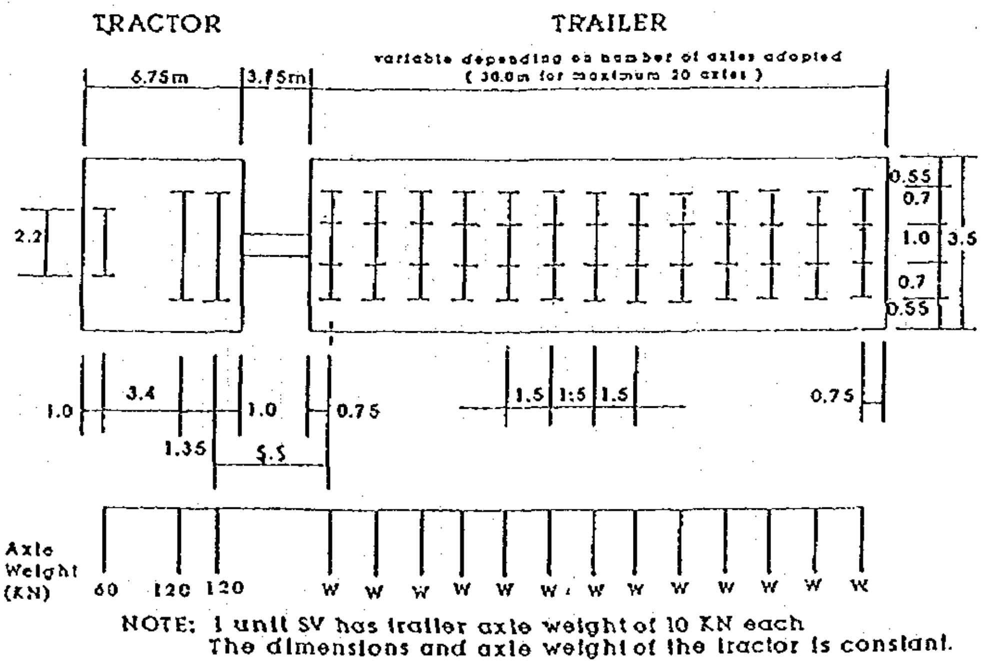
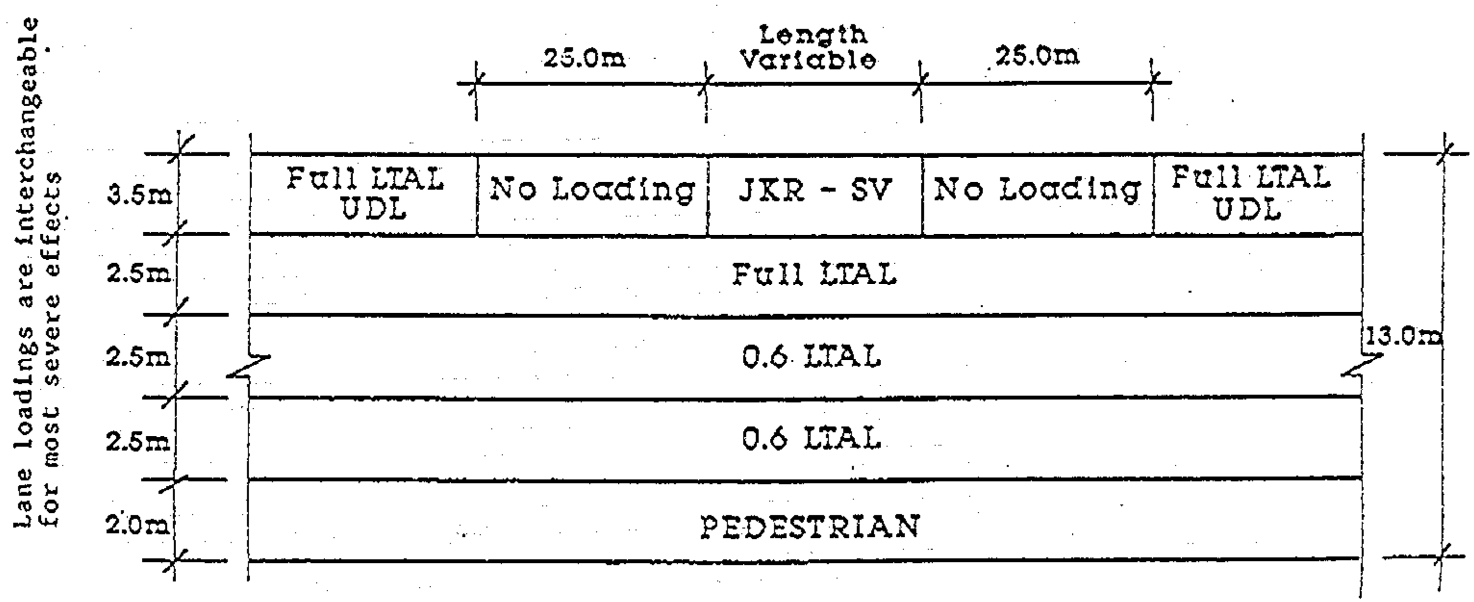


Fig. C.2 Plan of SV

where, one unit of SV shall be taken as equal to 10 kN per trailer axle plus the constant tractor axlesof a single 60 kN axle and two 120 kN axles. The 20units and 7units SV loadings shall be applied as the centre-line controlled and the uncontrolled SV movement respectively.



Uncontrolled SV movement for R5 Standard Carriageway

(3) **BD 37/88**

(a) HA loading

- UDL

$W = 336 (1/L)^{0.67}$ $L <= 50$ m

$W = 36 (1/L)^{0.1}$ $50m < L < 1600$ m

where, W = load per metre of lane (in kN)

L = loaded length (in m)

- KEL

The KEL per notional lane shall be taken as 120 kN.

where, the lane factors given in Table D-1 shall be applied.

Table C.1 HA lane factors

Loaded length L m	First lane factor $\beta 1$	Second lane factor $\beta 2$	Third lane factor $\beta 3$	Fourth& Subsequent lane factor βn
0 < L < 20m	$\alpha 1$	$\alpha 1$	0.6	$0.6\alpha 1$
20 <L < 40m	$\alpha 2$	$\alpha 2$	0.6	$0.6\alpha 2$
40 < L < 50m	1.0	1.0	0.6	0.6

Note : $\alpha 1 = 0.274$ bL and cannot exceed 1.0
$\alpha 2 = 0.0137 [bL (40 - L) + 3.65 (L - 20)]$

(a) HB loading

HB loading shall be considered same as BS5400 , but the minimum number of units shall normally be considered is 30.

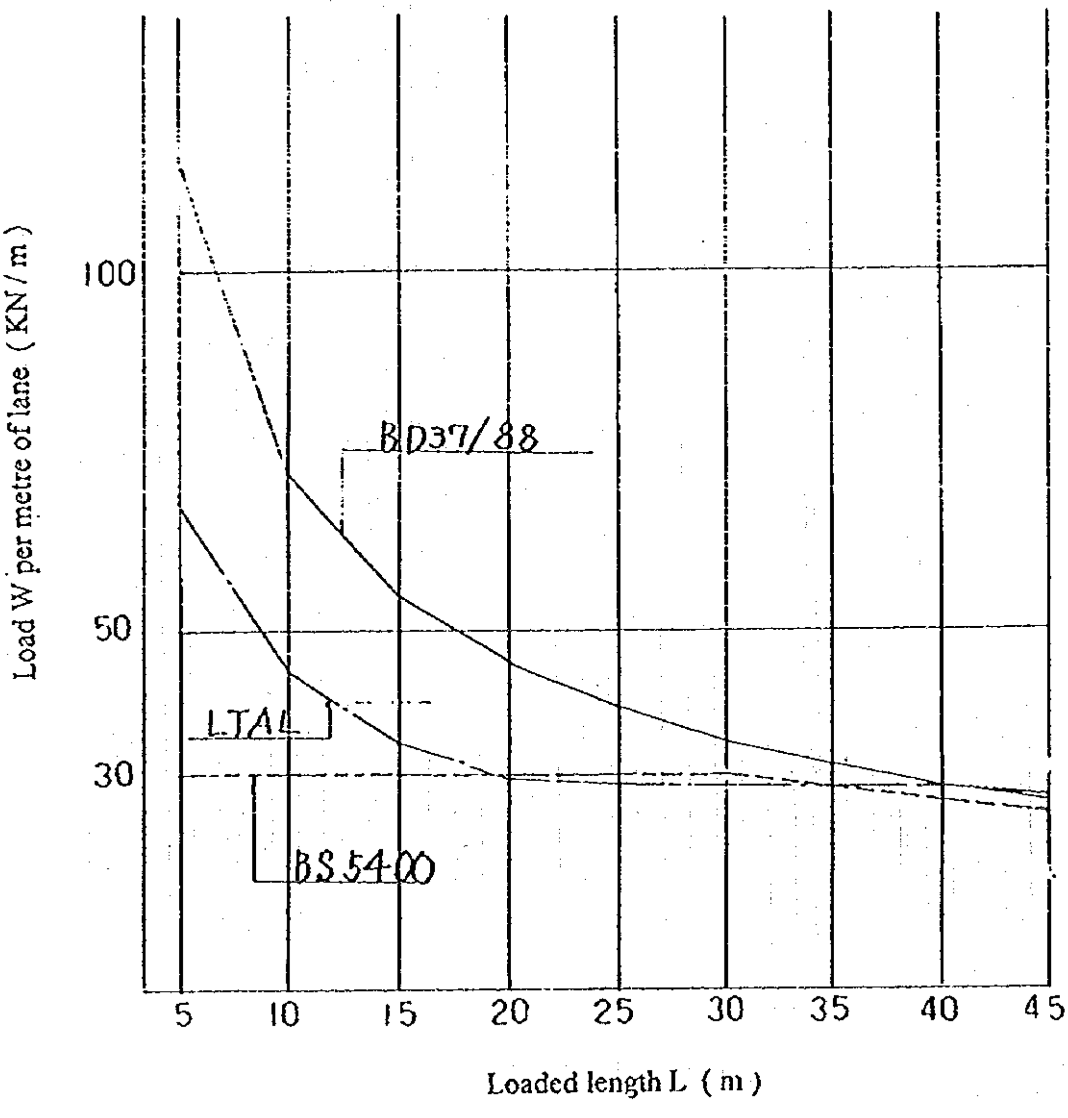


Fig. C - 3 Comparison of Loading curve for normal UDL

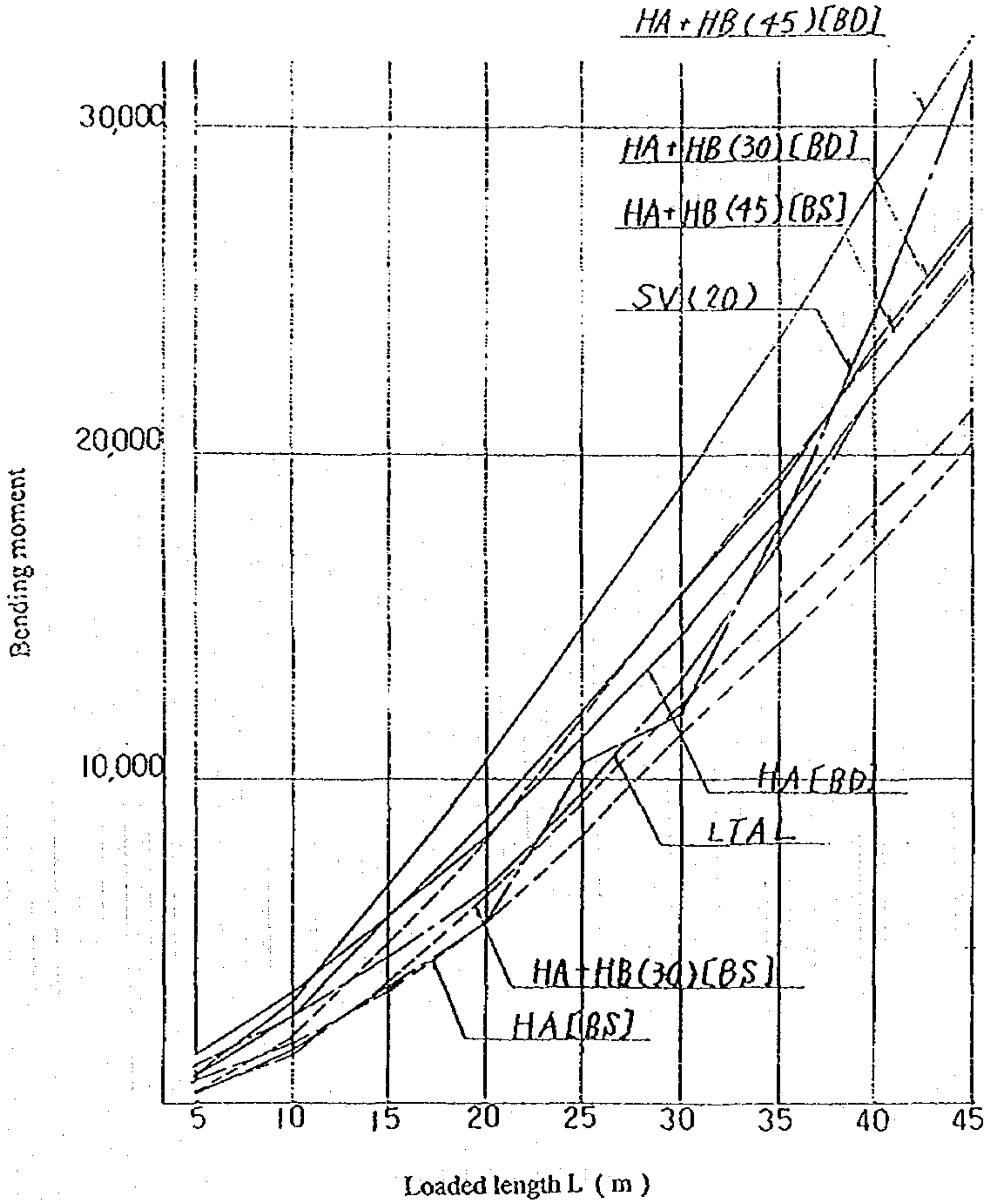


Fig. C -4 Comparison of Bending moment based on several Standards
(Bending moment is given at midspan for R5/U5)

Table C.2 A point of differences on BS5400 and BD37/88 for loadings except live load

Items	BD37/88		BS5400	
	Clause	Supplemental Applications	Clause	Applications
Carriageway width and number of notional lanes	3.2.9	1. The notional lane width shall be measured in a direction at right angles to the lane of the raised kerbs, lane marks or edge marking.	3.2.9	no specified
		2. Carriageway widths of 5.00m or more.		4.6m or more.
		3. Notional lanes shall be taken to be not less than 2.5m nor more than 3.65m wide.		2.3 < width < 3.8m
Combinations of loads	4.4	Amendment of Table 1.	4.4	Table 1
Design of Foundations	4.7	Based on BS8004.	4.7	Based on CP2004
Dead load	5.1	The densities of the material shall be given in BS648.	5.1	no specified
Superimposed dead load	5.2	The densities of the material shall be given in BS648.	5.2	no specified
	5.2.2	The factor rfL of the other loads except the deck surfacing shall be taken as 1.2 and 1.0 for the U.L.S and S.L.S respectively.	5.2.2	no specified
Aerodynamic effects for wind load	5.3.9	Not to be considered for effective span greater than 50m highway bridges and 30m foot / cycle track bridges respectively.	5.3.9	no specified
Temperature	5.4.1(a)	The effective temperature is a theorical temperature calculated by weighting and adding temperatures measured at various levels within the superstructure.	5.4.1(a)	no specified
Coefficient of thermal expansion	5.4.6	$7*10^{-6}$/℃ shall be adopted when limestone aggregates are used in concrete.	5.4.6	$9*10^{-6}$/℃
Differential settlement	5.6.3	With 95 % probability , rfL shall be given for the differential settlement.	none	no specified
Exceptional loads for abnormal indivisible live loads	5.7.2	rfL shall be taken as specified for HB loading.	5.7.2	no specified
Design load of earth pressure on retaining structures	5.8.1.2	Specified for vertical and non-vertical load.	5.8.1.2	only non-vertical loads
Live load surcharge	5.8.2.2	Specified for load combinations 1 to 5.	5.8.2.2	1 to 4
Footway and cycle track loading	6.5	New regulation.	none	no specified
Accidental wheel loading	6.6	New regulation.	none	no specified
Loads due to vehicle collision with parapet	6.7	This load shall be considered the local effects and global effects.	6.8	only local effects
Vehicle collision loads on highway bridge supports and superstructures	6.8	This load shall be considered on supports and superstructure.	6.9	only supports
Centrifugal loads	6.9	Application : R < 1000 m	6.5	no specified
		The nominal load Fc : 4000 / (r + 150) KN		3000 / (r + 150)
		Associated nominal primary live load : 400 KN + 6m length distribution		300 KN + 5m
Longitudinal load	6.10.1	The nominal load for HA : 8 KN/m + 250 <= 750 KN	6.6.1	8KN/m+200KN<=700KN
Accidental load due to skidding	6.11.1	The nominal load shall be taken as 300 KN.	6.7.1	250 KN

APPENDIX D

METEOROLOGICAL AND HYDROLOGICAL CONDITION OF MALAYSIA

APPENDIX D METEOROLOGICAL AND HYDROLOGICAL CONDITION OF MALAYSIA

1. General

In order to utilize a bridge crossing river or drainage channel for a long period, it is really important to make hydrological consideration well in the planning and designing stage of the bridge. This is because, there are many examples of increased flood damages by bridges as well as decreased structural safety of bridges due to erosion of river banks and bridge foundations.

This report shows general meteorological and hydrological conditions of Malaysia. This information will be one of a reference for considering meteorological and hydrological characteristics of the area around the bridge to be planned and designed.

2. Meteo-hydrological Condition and River Condition of Malaysia

2.1 Meteo-hydrological Condition

(1) General Climate

As Malaysia is equatorial country, its climate is generally characterized as uniform temperature, high humidity and much rainfall amount. There are four seasons caused by the Southwest Monsoon and the Northeast Monsoon. The four seasons are the southwest monsoon season, northeast monsoon season and the two inter monsoon seasons between them.

Southwest Monsoon Season:
The Southwest Monsoon season starts in the later half of May or early June and ends in September. It is caused by the southwest wind from

Indian Ocean. Wind speed is less than about 8 m/s. There are fairly heavy rainfalls in the west coast of Peninsular Malaysia in this season.

Northeast Monsoon Season:
The Northeast Monsoon Season starts in early November and ends in March. It is caused by the steady east or northeast winds from the South China Sea. Wind speed is about 5 to 15 m/s. There are heavy rainfalls in the northeastern part of Peninsular Malaysia, northern part of Sabah and the southern part of Sarawak.

Inter Monsoon Seasons:
During the two inter monsoon seasons, equatorial trough lies over Malaysia. The first inter monsoon season between March and May is a relatively dry season in Peninsular Malaysia as well as Sabah and Sarawak. During the second inter monsoon season between September and November, the biggest and fairly big amount of seasonal rainfall can be observed in the west coast of Peninsular Malaysia and east part of Sabah respectively.

(2) Meteo-hydrological Data

Meteorological observation is conducted by the Malaysian Meteorological Service (MMS). MMS has 31 principal meteorological stations, 114 climatological stations and 160 rainfall stations in all over Malaysia. Observation for rainfall is also conducted by the Department of Irrigation and Drainage (DID). List and locations of the principal meteorological stations are shown in Table D.1 and Fig. D.1 respectively.

Historical meteorological data were collected for the above principal meteorological stations in this study. The data are composed of temperature, relative humidity, rainfall amount, number of rainy days, evaporation and recorded maximum wind speed. Table D.2 shows the list of collected data with their durations. Followings describe calculated monthly values of the above meteorological data in this study.

1) Temperature

Table D.3 shows daily mean, mean daily maximum and mean daily minimum temperature of the principal meteorological stations.

Seasonal variation of the temperature of Peninsular Malaysia as well as Sabah and Sarawak is very small. The temperature ranges from 22 deg. C to 33 deg. C with the average of about 27 deg. C in the whole seasons for both of Peninsular Malaysia and Sabah and Sarawak.

2) Relative Humidity

Daily mean, mean daily maximum and mean daily minimum relative humidity is shown in Table D.4.

Seasonal variation of relative humidity is also very small in Peninsular Malaysia as well as in Sabah and Sarawak. The relative humidity ranges from 52 % to 99 % with the average of about 80 to 87 % for the whole Malaysia.

3) Rainfall

Amount of monthly and annual average rainfall, number of monthly and annual average rainy days and amount of recorded maximum 1 day rainfall and their occurrence dates for the principal meteorological stations are shown in Table D.5, Table D.6 and Table D.7 respectively. Tendency of annual rainfall amount for Peninsular Malaysia and Sabah and Sarawak are as follows;

a)	Peninsular Malaysia:	1700 - 2950 mm/year
	- Eastern and northeastern area (Pahang, Terengganu, Kelantan):	1900 - 2950 mm/year
	- Northwestern area (Perlis, Kedah, Pulau Pinang, Perak):	1700 - 2450 mm/year
b)	Sabah:	2000 - 3000 mm/year
c)	Sarawak:	2800 - 4100 mm/year

2.2 River Condition

River condition of Malaysia including characteristics of major rivers, record of big floods, existing and on-going studies of river and urban drainage are described.

(1) Major Rivers

List of major rivers of Malaysia is shown in Table D.10. They are the major rivers which have catchment areas of more than 1,000 km^2 in general.

Among the major rivers in Peninsular Malaysia, the Pahang river has the greatest catchment area of 29,300 km^2. The Perak river has the second catchment area of 14,700 km^2. In general, the rivers in Peninsular Malaysia have steep profile in the upstream reaches and gentle profile in the midstream and downstream reaches.

Among the major rivers in Sabah and Sarawak, the Rajang river in Sarawak has the greatest catchment area of 51,053 km^2. The Baram river in Sarawak has the second catchment area of 22,325 km^2 and the Kinabatangan river in Sabah has the third catchment area of 16,755 km^2.

The rivers in Sarawak have generally gentle profile with meandering. The rivers in Sabah generally have relatively steep profile with strong current.

(2) Recorded Major Floods

Table D.11 shows the recorded major floods in Malaysia. In recent years, major floods occurred in 1971, 1973, 1979, 1981, 1983, 1986 and 1988. The Pahang, Kelantan, Terengganu, Kuantan and Kelang rivers are among the major rivers which have had big floods in the past.

(3) Existing Plans for Flood Control and Drainage Improvement

In the planning and designing stage of bridges for river or drainage channel, it is important to follow the existing plans for flood control and drainage improvement. Design flood discharge, design river cross section, design high water level and free board at the bridge site are necessary to be determined referring the above existing plans.

Table D.12 shows the existing major studies of flood control and urban drainage improvement of Malaysia.

Table D.1 List of Principal Meteorological Stations in Malaysia

No.	Station Name	Location		Height	Date of
		Latitude (° N)	Longitude (° E)	above M.S.L.(m)	Commencement
PENINSULAR MALAYSIA					
	Johor				
1.	Johor Baru International Airport (Senai)	1° 38'	103° 40'	37.8	Mar. 01, 1974
2.	Kluang	2° 01'	103° 19'	88.1	Jan. 01, 1974
3.	Mersing	2° 27'	103° 50'	43.6	1930
	Kedah				
4.	Alor Setar Airport (Kepala Batas)	6° 12'	100° 24'	3.9	1930
5.	Pulau Langkawi International Airport	6° 20'	99° 44'	6.4	Jul. 01, 1987
	Kelantan				
6.	Kota Bharu Airport (Pengkalan Chepa)	6° 10'	102° 17'	4.6	1930
7.	Kuala Krai	5° 32'	102° 12'	68.3	Jan. 01, 1985
	Malacca				
8.	Malacca Airport (Batu Berendam)	2° 16'	102° 15'	8.5	1930
	Pahang				
9.	Batu Embun	3° 58'	102° 21'	59.5	Jan. 01, 1983
10.	Cameron Highlands (Tanah Rata)	4° 28'	101° 22'	1545.0	Apr. 01, 1983
11.	Kuantan Airport	3° 47'	103° 13'	15.3	1930
12.	Muadzam Shah	3° 03'	103° 05'	33.3	Aug. 01, 1983
13.	Temerloh	3° 28'	102° 23'	39.1	Aug. 01, 1978
	Pulau Pinan				
14.	Butterworth Airport	5° 28'	100° 23'	2.8	Jan. 01, 1985
15.	Penang Internatonal Airport (Bayan Lepas)	5° 18'	100° 16'	2.8	1934
	Perak				
16.	Ipoh Airport	4° 34'	101° 06'	40.1	1930
17.	Sitiawan	4° 13'	100° 42'	7.0	1931
	Perlis				
18.	Chuping	6° 29'	100° 16'	21.7	Jan. 01, 1980
	Selangor				
19.	Kuala Lumpur International Airport (Subang)	3° 07'	101° 33'	16.5	Aug. 01, 1965
20.	Petaling Jaya	3° 06'	101° 39'	45.7	Jan. 01, 1973
	Terengganu				
21.	Kuala Terengganu Airport	5° 23'	103° 06'	5.2	Jan. 01, 1985
21'.	Kajiklim Utama Kuala Terengganu (former Sta.21)	5° 20'	103° 08'	35.1	1930
SABAH AND SARAWAK					
	Sabah				
22.	Kota Kinabalu International Airport	5° 56'	116° 03'	2.3	1947
23.	Kudat Airport	6° 55'	116° 50'	3.5	Jan. 01, 1983
24.	Sandakan Airport	5° 54'	118° 04'	10.3	1947
25.	Tawau Airport	4° 16'	117° 53'	19.8	Jul. 01, 1979
	Sarawak				
26.	Bintulu Airport	3° 12'	113° 02'	3.1	1947
27.	Kuching International Airport	1° 29'	110° 20'	21.7	1947
28.	Miri Airport	4° 20'	113° 59'	17.0	1947
29.	Sibu Airport	2° 20'	111° 50'	7.5	1962
30.	Sri Aman Airport	1° 13'	111° 27'	9.6	Jan. 01, 1983
	Labuan				
31.	Labuan Airport	5° 18'	115° 15'	29.3	Nov. 01, 1978

Table D.2 Duration of Meteorological Data Collected(1/2)

No.	Station Name	Date of Commencement	Temperature & Relative Humidity	Monthly Rainfall & No.	Highest Rainfall in a Day	Mean Daily Evaporation	Maximum Surface Wind
PENINSULAR MALAYSIA							
	Johor						
1.	Johor Baru International Airport (Senai)	Mar. 01, 1974	1974 - 1991	1974 - 1993	1974 - 1993	1974 - 1993	1974 - 1993
2.	Kluang	Jan. 01, 1974	1974 - 1991	1974 - 1993	1974 - 1992	1974 - 1993	1974 - 1993
3.	Mersing	1930	1968 - 1991	1951 - 1993	1951 - 1993	1974 - 1993	1939 - 1993
	Kedah						
4.	Alor Setar Airport (Kepala Batas)	1930	1968 - 1991	1951 - 1993	1951 - 1993	1974 - 1993	1939 - 1993
5.	Pulau Langkawi International Airport	Jul. 01, 1987	1987 - 1991	1987 - 1993	1987 - 1993	1987 - 1993	1987 - 1993
	Kelantan						
6.	Kota Bharu Airport (Pengkalan Chepa)	1930	1968 - 1991	1951 - 1993	1951 - 1993	1968 - 1993	1939 - 1993
7.	Kuala Krai	Jan. 01, 1985	1985 - 1991	1985 - 1993	1985 - 1993	1984 - 1993	1985 - 1993
	Malacca						
8.	Malacca Airport (Batu Berendam)	1930	1968 - 1991	1951 - 1993	1951 - 1993	1968 - 1993	1941 - 1993
	Pahang						
9.	Batu Embun	Jan. 01, 1983	1982 - 1991	1982 - 1993	1982 - 1993	1982 - 1993	1982 - 1993
10.	Cameron Highlands (Tanah Rata)	Apr. 01, 1983	1968 - 1992	1951 - 1993	1951 - 1993	1973 - 1993	1939 - 1987
11.	Kuantan Airport	1930	1968 - 1991	1951 - 1993	1951 - 1993	1974 - 1993	1950 - 1993
12.	Muadzam Shah	Aug. 01, 1983	1983 - 1991	1983 - 1993	1983 - 1993	1983 - 1993	1983 - 1993
13.	Temerloh	Aug. 01, 1978	1979 - 1991	1978 - 1993	1978 - 1993	1979 - 1993	1978 - 1993
	Pulau Pinan						
14.	Butterworth Airport	Jan. 01, 1985	1985 - 1991	1969 - 1993	1969 - 1993	-	1985 - 1993
15.	Penang Internatonal Airport (Bayan Lepas)	1934	1968 - 1991	1951 - 1993	1951 - 1993	1974 - 1993	1939 - 1993
	Perak						
16.	Ipoh Airport	1930	1968 - 1991	1951 - 1993	1951 - 1993	1974 - 1993	1939 - 1993
17.	Sitiawan	1931	1968 - 1991	1951 - 1993	1951 - 1993	1974 - 1993	1939 - 1993

Table D.2 Duration of Meteorological Data Collected(2/2)

No.	Station Name	Date of Commencement	Temperature & Relative Humidity	Monthly Rainfall & No.	Highest Rainfall in a Day	Mean Daily Evaporation	Maximum Surface Wind
	Perlis						
18.	Chuping	Jan. 01, 1980	1979 - 1991	1979 - 1993	1979 - 1993	1979 - 1993	1979 - 1993
	Selangor						
19.	Kuala Lumpur International Airport (Subang)	Aug. 01, 1965	1968 - 1991	1966 - 1993	1966 - 1993	1968 - 1993	1966 - 1993
20.	Petaling Jaya	Jan. 01, 1973	1971 - 1991	1969 - 1993	1971 - 1993	1971 - 1993	1971 - 1993
	Terengganu						
21.	Kuala Terengganu Airport	Jan. 01, 1985	1985 - 1991	1985 - 1993	1985 - 1993	1985 - 1993	1985 - 1993
21'	Kajiklim Utama Kuala Terengganu	-	1968 - 1991	1951 - 1993	1951 - 1993	1974 - 1993	1939 - 1993
SABAH AND SARAWAK							
	Sabah						
22.	Kota Kinabalu International Airport	1947	1968 - 1991	1951 - 1993	1951 - 1993	1971 - 1993	1954 - 1993
23.	Kudat Airport	Jan. 01, 1983	1982 - 1991	1955 - 1993	1955 - 1993	1981 - 1993	1981 - 1993
24.	Sandakan Airport	1947	1968 - 1991	1951 - 1993	1951 - 1993	1972 - 1993	1954 - 1993
25.	Tawau Airport	Jul. 01, 1979	1980 - 1991	1951 - 1993	1951 - 1993	1979 - 1993	1979 - 1993
	Sarawak						
26.	Bintulu Airport	1947	1968 - 1991	1951 - 1993	1951 - 1993	1968 - 1993	1964 - 1993
27.	Kuching International Airport	1947	1968 - 1991	1951 - 1993	1951 - 1993	1968 - 1993	1954 - 1993
28.	Miri Airport	1947	1968 - 1991	1951 - 1993	1951 - 1993	1968 - 1993	1964 - 1993
29.	Sibu Airport	1962	1968 - 1991	1962 - 1993	1962 - 1993	1968 - 1993	1964 - 1993
30.	Sri Aman Airport	Jan. 01, 1983	1983 - 1991	1983 - 1993	1983 - 1993	1983 - 1993	1983 - 1993
	Labuan						
31.	Labuan Airport	Nov. 01, 1978	1979 - 1991	1951 - 1993	1951 - 1993	1979 - 1993	1939 - 1993

Table D.3 Temperature of the Principal Meteorological Stations (1/3)
- Monthly Average of Daily Mean Temperature

(Unit: °C)

NO.	STATION NAME	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
	PENINSULAR MALAYSIA													
	Johor													
1.	Johor Baru International Airport (Senai)	25.3	25.7	26.0	26.2	26.3	26.3	25.8	25.8	25.6	25.8	25.5	25.3	25.8
2.	Kluang	25.3	26.0	26.4	26.4	26.5	26.4	25.9	25.9	25.7	25.9	25.5	25.1	25.9
3.	Mersing	25.8	26.3	26.7	26.8	26.6	26.3	25.9	25.9	25.7	25.9	25.6	25.5	26.1
	Kedah													
4.	Alor Setar Airport (Kepala Batas)	26.6	27.5	27.8	27.9	27.6	27.4	26.9	26.9	26.6	26.5	26.3	26.3	27.0
5.	Pulau Langkawi International Airport	27.7	28.0	28.0	27.8	27.5	27.5	27.2	27.1	26.7	26.7	27.1	27.2	27.4
	Kelantan													
6.	Kota Bharu Airport (Pengkalan Chepa)	25.6	26.1	26.9	27.8	28.0	27.6	27.1	27.0	26.8	26.6	26.0	25.7	26.8
7.	Kuala Krai	24.6	25.6	26.4	27.0	26.9	26.9	26.3	26.2	25.8	25.7	25.2	24.4	25.9
	Malacca													
8.	Malacca Airport (Batu Berendam)	26.2	26.9	27.0	27.1	27.1	26.9	26.5	26.4	26.4	26.5	26.2	26.0	26.6
	Pahang													
9.	Batu Embun	25.3	26.2	26.9	27.3	27.1	26.9	26.4	26.4	26.1	26.2	25.9	25.0	26.3
10.	Cameron Highlands (Tanah Rata)	17.1	17.7	18.3	18.8	18.7	18.5	18.0	17.9	17.6	17.7	17.6	17.1	17.9
11.	Kuantan Airport	24.7	25.3	26.0	26.7	27.0	26.9	26.4	26.5	26.3	26.1	25.3	24.7	26.0
12.	Muadzam Shah	25.4	25.9	26.3	26.9	26.9	26.9	26.3	26.3	26.2	26.2	25.9	25.3	26.2
13.	Temerloh	25.5	26.5	27.1	27.3	27.3	27.1	26.7	26.7	26.4	26.5	26.0	25.3	26.5
	Pulau Pinan													
14.	Butterworth Airport	27.2	27.6	27.6	27.9	27.8	28.0	27.3	27.3	26.6	26.6	26.7	26.9	27.3
15.	Penang Internatonal Airport (Bayan Lepas)	27.1	27.5	27.7	27.7	27.5	27.4	27.0	26.9	26.5	26.5	26.6	26.8	27.1
	Perak													
16.	Ipoh Airport	26.5	27.0	27.3	27.3	27.4	27.4	27.0	26.9	26.5	26.3	26.1	26.1	26.8
17.	Sitiawan	26.1	26.7	27.0	27.3	27.3	27.2	26.7	26.8	26.5	26.4	26.2	26.0	26.7
	Perlis													
18.	Chuping	26.8	27.7	28.0	27.8	27.4	27.1	26.7	26.7	26.3	26.3	26.1	26.1	26.9
	Selangor													
19.	Kuala Lumpur International Airport (Subang)	26.1	26.6	26.9	27.0	27.2	27.1	26.6	26.6	26.4	26.4	26.1	26.0	26.6
20.	Petaling Jaya	26.7	27.1	27.4	27.4	27.7	27.7	27.2	27.2	26.9	26.9	26.5	26.5	27.1
	Terengganu													
21.	Kuala Terengganu Airport	26.0	26.4	27.1	27.7	27.7	27.5	27.0	26.9	26.7	26.6	26.2	26.2	26.8
21'	Kajiklim Utama Kuala Terengganu	25.2	25.7	26.4	27.1	27.3	27.1	26.6	26.5	26.3	26.1	25.5	25.4	26.3
	SABAH AND SARAWAK													
	Sabah													
22.	Kota Kinabalu International Airport	26.1	26.3	27.0	27.7	27.6	27.4	27.1	27.1	26.9	27.0	26.6	26.5	26.9
23.	Kudat Airport	26.7	26.8	27.6	28.2	28.2	27.7	27.1	27.2	27.2	26.9	26.9	26.7	27.3
24.	Sandakan Airport	26.4	26.5	27.1	27.7	27.8	27.5	27.2	27.2	27.1	27.0	26.8	26.5	27.1
25.	Tawau Airport	26.1	26.1	26.7	27.0	27.2	26.9	26.5	26.6	26.5	26.7	26.7	26.3	26.6
	Sarawak													
26.	Bintulu Airport	25.9	26.1	26.5	26.9	27.1	27.0	26.7	26.7	26.6	26.5	26.3	26.1	26.5
27.	Kuching International Airport	25.4	25.8	26.2	26.6	26.9	26.8	26.6	26.5	26.3	26.0	25.8	25.6	26.2
28.	Miri Airport	25.8	26.0	26.6	27.1	27.3	27.1	26.8	26.9	26.7	26.6	26.4	26.2	26.6
29.	Sibu Airport	25.5	25.8	26.2	26.5	26.8	26.9	26.5	26.5	26.3	26.2	26.1	25.8	26.3
30.	Sri Aman Airport	25.6	26.0	26.2	26.6	26.7	26.8	26.2	26.3	26.2	26.1	25.8	25.7	26.2
	Labuan													
31.	Labuan Airport	26.8	26.9	27.5	28.1	28.1	27.8	27.4	27.7	27.4	27.3	27.2	27.2	27.5

Table D.3 Temperature of the Principal Meteorological Stations (2/3)
- Monthly Average of Daily Maximum Temperature

(Unit: °C)

NO.	STATION NAME	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
PENINSULAR MALAYSIA														
	Johor													
1.	Johor Baru International Airport (Senai)	30.7	31.9	32.4	32.6	32.2	31.9	31.3	31.3	31.3	31.7	31.1	30.3	31.5
2.	Kluang	29.8	31.4	32.4	32.5	32.3	31.9	31.2	31.4	31.3	31.6	30.7	29.5	31.3
3.	Mersing	28.2	29.1	30.3	31.5	31.9	31.4	30.9	31.0	30.9	31.0	29.6	28.1	30.3
	Kedah													
4.	Alor Setar Airport (Kepala Batas)	32.7	34.4	34.5	33.7	32.4	31.9	31.5	31.6	31.1	31.3	31.4	31.4	32.3
5.	Pulau Langkawi International Airport	32.8	33.3	32.8	31.9	30.8	31.0	30.5	30.4	29.9	30.2	30.8	31.3	31.3
	Kelantan													
6.	Kota Bharu Airport (Pengkalan Chepa)	29.1	30.1	31.3	32.5	32.8	32.4	32.0	31.9	31.6	31.0	29.5	28.8	31.1
7.	Kuala Krai	30.1	32.4	33.4	34.6	33.9	33.5	33.1	32.8	32.5	32.3	30.7	29.3	32.4
	Malacca													
8.	Malacca Airport (Batu Berendam)	31.6	32.9	33.0	32.5	31.9	31.6	31.1	31.1	31.0	31.5	31.1	31.0	31.7
	Pahang													
9.	Batu Embun	30.8	32.7	33.4	34.0	33.4	33.1	32.7	32.8	32.4	32.3	31.4	30.0	32.4
10.	Cameron Highlands (Tanah Rata)	20.9	22.1	22.7	23.0	22.8	22.4	22.0	21.6	21.5	21.6	21.3	20.6	21.9
11.	Kuantan Airport	29.5	30.7	31.6	32.6	32.9	32.7	32.4	32.5	32.2	31.9	30.3	28.9	31.5
12.	Muadzam Shah	29.5	31.2	31.7	32.9	33.0	32.9	32.5	32.7	32.4	32.3	30.9	29.2	31.8
13.	Temerloh	30.9	32.7	33.5	33.9	33.5	33.3	33.1	33.3	32.8	32.7	31.6	30.2	32.6
	Pulau Pinang													
14.	Butterworth Airport	32.2	32.3	32.3	32.2	31.9	32.1	31.5	31.3	30.6	30.7	31.0	31.8	31.7
15.	Penang Internatonal Airport (Bayan Lepas)	31.7	32.2	32.2	31.9	31.5	31.5	31.1	31.0	30.5	30.5	30.7	31.1	31.3
	Perak													
16.	Ipoh Airport	32.8	33.8	33.9	33.6	33.3	33.3	32.9	32.9	32.4	32.3	31.9	32.0	32.9
17.	Sitiawan	31.5	32.3	32.6	32.5	32.5	32.6	32.2	32.2	31.7	31.4	31.1	31.2	32.0
	Perlis													
18.	Chuping	32.9	34.9	35.0	34.0	32.6	32.2	31.8	31.7	31.4	31.5	31.4	31.2	32.5
	Selangor													
19.	Kuala Lumpur International Airport (Subang)	31.9	32.8	33.1	32.9	32.7	32.5	32.1	32.3	31.9	31.9	31.4	31.4	32.2
20.	Petaling Jaya	32.5	33.3	33.6	33.5	33.3	33.1	32.6	32.7	32.5	32.6	32.0	32.0	32.8
	Terengganu													
21.	Kuala Terengganu Airport	29.1	30.1	31.0	32.3	32.5	32.4	32.0	31.8	31.5	31.1	29.9	29.0	31.1
21'	Kajiklim Utama Kuala Terengganu	28.3	29.2	30.4	31.5	32.1	31.8	31.3	31.3	30.9	30.5	29.0	28.1	30.4
SABAH AND SARAWAK														
	Sabah													
22.	Kota Kinabalu International Airport	30.0	30.4	31.3	31.9	31.9	31.5	31.2	31.3	31.1	30.9	30.7	30.6	31.1
23.	Kudat Airport	29.7	30.2	31.4	32.6	33.0	32.5	31.9	32.1	31.8	31.4	30.8	30.1	31.5
24.	Sandakan Airport	29.3	29.6	30.7	31.7	32.6	32.4	32.3	32.5	32.1	31.7	30.8	29.9	31.3
25.	Tawau Airport	31.5	31.4	32.0	32.2	32.3	31.7	31.3	31.5	31.7	31.9	32.1	31.9	31.8
	Sarawak													
26.	Bintulu Airport	29.5	29.7	30.3	31.1	31.5	31.6	31.3	31.3	31.0	30.8	30.5	30.2	30.7
27.	Kuching International Airport	29.7	30.3	31.2	32.3	32.8	32.7	32.4	32.4	32.1	32.0	31.5	30.6	31.7
28.	Miri Airport	29.8	30.1	30.8	31.3	31.5	31.4	31.1	31.2	30.9	30.6	30.4	30.2	30.8
29.	Sibu Airport	30.5	31.2	31.9	32.7	33.0	32.9	32.7	32.7	32.2	32.2	31.8	31.1	32.1
30.	Sri Aman Airport	30.8	31.4	31.9	32.3	32.3	32.7	32.1	32.2	32.1	32.0	31.7	31.0	31.9
	Labuan													
31.	Labuan Airport	29.8	30.3	31.6	32.1	31.7	31.5	31.0	31.3	31.1	30.8	30.7	30.4	31.0

Table D.3 Temperature of the Principal Meteorological Stations (3/3)
- Monthly Average of Daily Minimum Temperature

(Unit: °C)

NO.	STATION NAME	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
PENINSULAR MALAYSIA														
	Johor													
1.	Johor Baru International Airport (Senai)	21.7	21.8	22.1	22.7	22.9	22.7	22.3	22.2	22.3	22.4	22.5	22.2	22.3
2.	Kluang	22.4	22.7	22.9	23.0	23.2	23.1	22.6	22.6	22.4	22.6	22.6	22.5	22.7
3.	Mersing	23.5	23.6	23.3	23.0	23.1	22.9	22.4	22.4	22.3	22.5	22.7	23.2	22.9
	Kedah													
4.	Alor Setar Airport (Kepala Batas)	21.8	22.2	22.9	23.9	24.3	24.0	23.5	23.5	23.5	23.5	23.2	22.6	23.2
5.	Pulau Langkawi International Airport	23.9	23.9	24.3	24.6	24.8	24.6	24.3	24.3	24.1	24.1	24.3	24.0	24.3
	Kelantan													
6.	Kota Bharu Airport (Pengkalan Chepa)	22.5	22.6	23.1	23.8	24.3	23.9	23.5	23.4	23.3	23.4	23.3	23.2	23.3
7.	Kuala Krai	21.4	21.3	22.4	22.9	23.2	22.9	22.5	22.5	22.4	22.6	22.5	21.8	22.4
	Malacca													
8.	Malacca Airport (Batu Berendam)	22.5	23.0	23.2	23.4	23.5	23.1	22.8	22.7	22.8	23.0	22.9	22.7	23.0
	Pahang													
9.	Batu Embun	21.7	21.8	22.6	23.2	23.3	22.9	22.3	22.4	22.5	22.7	22.7	22.1	22.5
10.	Cameron Highlands (Tanah Rata)	14.4	14.5	15.1	15.8	16.0	15.5	15.1	15.2	15.1	15.2	15.1	14.7	15.1
11.	Kuantan Airport	21.6	21.7	22.3	23.0	23.3	23.1	22.7	22.7	22.7	22.7	22.6	22.2	22.5
12.	Muadzam Shah	22.3	22.1	22.5	23.0	23.2	22.8	22.3	22.3	22.4	22.6	22.8	22.6	22.6
13.	Temerloh	21.9	22.2	22.9	23.5	23.6	23.2	22.6	22.6	22.8	22.9	22.9	22.3	22.8
	Pulau Pinan													
14.	Butterworth Airport	23.0	23.2	23.5	24.2	24.3	24.1	23.6	23.6	23.5	23.5	23.4	23.1	23.6
15.	Penang Internatonal Airport (Bayan Lepas)	23.3	23.5	23.8	24.2	24.2	23.9	23.5	23.5	23.3	23.3	23.4	23.5	23.6
	Perak													
16.	Ipoh Airport	22.3	22.7	23.1	23.7	23.7	23.4	22.9	23.0	22.9	22.9	22.9	22.5	23.0
17.	Sitiawan	22.3	22.7	23.1	23.6	23.7	23.3	22.7	22.9	22.9	23.0	22.9	22.6	23.0
	Perlis													
18.	Chuping	23.0	23.3	23.7	24.0	24.1	23.8	23.3	23.4	23.4	23.3	23.3	23.1	23.5
	Selangor													
19.	Kuala Lumpur International Airport (Subang)	22.1	22.3	22.8	23.4	23.6	23.2	22.7	22.7	22.8	22.9	22.9	22.5	22.8
20.	Petaling Jaya	22.9	23.2	23.7	24.0	24.2	23.9	23.5	23.5	23.4	23.5	23.5	23.1	23.5
	Terengganu													
21.	Kuala Terengganu Airport	23.4	22.9	23.7	24.0	24.2	24.0	23.5	23.5	23.5	23.5	23.6	23.8	23.6
21'	Kajiklim Utama Kuala Terengganu	22.3	22.5	22.9	23.4	23.7	23.5	23.1	23.0	23.1	23.0	23.0	23.1	23.1
SABAH AND SARAWAK														
	Sabah													
22.	Kota Kinabalu International Airport	22.7	22.8	23.3	24.0	24.2	23.9	23.6	23.6	23.6	23.5	23.4	23.2	23.5
23	Kudat Airport	24.2	24.2	24.6	24.7	24.5	23.8	23.2	23.3	23.5	23.5	23.8	24.0	23.9
24.	Sandakan Airport	23.4	23.2	23.5	23.8	23.8	23.5	23.2	23.2	23.2	23.3	23.4	23.4	23.4
25.	Tawau Airport	22.3	22.2	22.5	23.1	23.5	23.3	22.8	22.9	22.7	22.9	23.0	22.7	22.8
	Sarawak													
26.	Bintulu Airport	23.2	23.2	23.5	23.7	23.8	23.6	23.2	23.2	23.2	23.3	23.2	23.2	23.3
27.	Kuching International Airport	22.7	22.9	23.1	23.3	23.5	23.1	22.9	22.9	22.8	22.8	22.8	22.8	23.0
28.	Miri Airport	22.9	22.9	23.3	23.6	23.7	23.5	23.1	23.1	23.1	23.3	23.2	23.1	23.2
29.	Sibu Airport	22.3	22.3	22.5	22.8	22.9	22.6	22.3	22.3	22.4	22.5	22.5	22.5	22.5
30.	Sri Aman Airport	22.9	22.9	23.1	23.3	23.3	22.9	22.4	22.5	22.7	22.8	22.8	22.8	22.9
	Labuan													
31.	Labuan Airport	24.5	24.4	24.7	25.2	25.1	24.9	24.4	24.7	24.5	24.3	24.4	24.5	24.6

Table D.4 Relative Humidity of the Principal Meteorological Stations (1/3)
- Monthly Average of Daily Mean Relative Humidity

(Unit: %)

NO.	STATION NAME	JAN.	FEB.	MAR.	APR	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
PENINSULAR MALAYSIA														
	Johor													
1.	Johor Baru International Airport (Senai)	85.6	84.0	85.8	88.0	88.4	87.2	87.6	87.7	88.0	87.8	88.9	88.0	87.3
2.	Kluang	84.8	83.0	83.9	87.0	87.6	86.5	87.1	86.8	87.5	87.1	88.6	87.8	86.5
3.	Mersing	82.7	82.2	82.9	85.3	86.6	86.7	87.1	87.0	87.2	87.1	88.2	86.7	85.8
	Kedah													
4.	Alor Setar Airport (Kepala Batas)	73.8	72.2	75.7	80.9	84.9	85.2	85.7	85.4	86.5	86.8	85.5	79.6	81.9
5.	Pulau Langkawi International Airport	71.9	72.9	76.9	82.7	85.7	84.7	85.3	85.7	86.8	86.5	82.2	74.3	81.3
	Kelantan													
6.	Kota Bharu Airport (Pengkalan Chepa)	81.3	80.3	80.3	80.3	80.7	81.1	81.8	82.6	83.3	84.6	86.7	84.0	82.3
7.	Kuala Krai	88.9	84.1	84.7	85.0	86.7	86.5	86.6	87.7	88.8	89.9	91.3	91.0	87.6
	Malacca													
8.	Malacca Airport (Batu Berendam)	79.4	78.3	81.5	85.1	85.7	85.6	85.5	85.9	86.0	85.7	86.8	83.7	84.1
	Pahang													
9.	Batu Embun	86.8	82.7	82.7	83.7	85.8	85.9	85.7	85.8	86.6	87.1	88.5	89.5	85.9
10.	Cameron Highlands (Tanah Rata)	87.5	87.0	87.8	90.3	91.7	88.3	89.6	90.6	92.0	92.0	91.9	90.7	89.9
11.	Kuantan Airport	86.1	84.4	84.6	84.9	85.5	84.8	84.6	84.3	85.2	86.7	89.5	89.4	85.8
12.	Muadzam Shah	84.8	83.2	85.5	85.7	86.2	84.8	85.0	84.8	85.8	86.3	88.0	86.7	85.6
13.	Temerloh	84.9	81.7	81.9	84.1	85.3	84.8	84.5	84.0	85.9	86.2	87.9	87.7	84.9
	Pulau Pinan													
14.	Butterworth Airport	74.6	75.7	80.0	82.5	83.8	81.5	82.2	82.7	85.6	86.1	84.0	76.9	81.3
15.	Penang Internatonal Airport (Bayan Lepas)	74.7	76.9	80.3	83.8	85.1	84.2	84.1	84.8	86.3	86.7	84.2	78.4	82.5
	Perak													
16.	Ipoh Airport	78.7	78.1	79.5	82.3	82.4	79.9	79.6	80.1	82.6	84.0	84.7	82.9	81.2
17.	Sitiawan	84.9	83.7	84.1	85.3	85.3	84.1	83.5	83.8	85.5	86.6	87.5	86.9	85.1
	Perlis													
18.	Chuping	75.7	73.7	76.7	83.0	87.0	86.7	86.8	87.0	88.2	88.5	87.2	81.7	83.5
	Selangor													
19.	Kuala Lumpur International Airport (Subang)	82.2	81.1	82.2	84.5	84.1	82.7	82.4	82.0	84.0	84.9	86.3	84.9	83.4
20.	Petaling Jaya	78.5	78.2	79.3	81.8	80.9	78.8	79.1	78.4	81.1	82.1	83.9	81.9	80.3
	Terengganu													
21.	Kuala Terengganu Airport	81.5	80.7	81.4	82.3	83.3	83.2	82.6	85.0	84.2	85.3	86.3	81.8	83.1
21'	Kajiklim Utama Kuala Terengganu	84.0	83.6	83.5	84.2	84.7	85.1	85.0	85.6	86.1	87.4	89.2	86.5	85.4
SABAH AND SARAWAK														
	Sabah													
22.	Kota Kinabalu International Airport	83.2	82.6	80.9	80.8	81.5	80.1	80.0	79.8	81.6	82.6	83.5	82.8	81.6
23.	Kudat Airport	85.3	84.5	82.1	81.8	81.7	81.4	82.2	82.0	83.2	84.3	86.3	85.9	83.4
24.	Sandakan Airport	84.7	83.8	81.9	82.1	83.1	83.5	83.3	83.1	84.4	84.5	85.9	86.3	83.9
25.	Tawau Airport	85.2	84.7	83.8	84.5	84.7	85.3	85.5	84.9	84.6	84.6	85.4	85.4	84.9
	Sarawak													
26.	Bintulu Airport	88.3	87.7	87.0	86.7	86.3	85.3	85.5	85.5	85.8	86.5	87.3	87.9	86.7
27.	Kuching International Airport	88.1	87.0	85.7	85.5	84.5	83.3	82.6	82.8	84.0	85.7	86.9	87.9	85.3
28.	Miri Airport	87.8	87.2	85.9	85.8	85.3	84.3	84.1	83.9	84.9	85.9	86.7	87.5	85.8
29.	Sibu Airport	89.6	88.6	87.8	87.4	86.6	85.3	85.2	85.3	86.6	87.0	87.7	88.9	87.2
30.	Sri Aman Airport	88.7	86.7	86.6	86.6	86.7	84.5	85.0	84.6	85.7	86.6	87.5	88.0	86.4
	Labuan													
31.	Labuan Airport	84.9	84.7	83.1	82.5	83.6	82.4	82.6	82.2	83.1	84.0	84.6	83.8	83.5

Table D.4 Relative Humidity of the Principal Meteorological Stations (2/3) - Monthly Average of Daily Maximum Relative Humidity

(Unit: %)

NO.	STATION NAME	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
PENINSULAR MALAYSIA														
	Johor													
1.	Johor Baru International Airport (Senai)	99.2	99.2	99.4	99.4	99.4	99.4	99.5	99.4	99.5	99.4	99.4	99.2	99.4
2.	Kluang	97.1	97.3	97.9	99.0	99.1	98.9	99.1	98.9	99.2	99.1	99.3	98.3	98.6
3.	Mersing	92.1	92.4	94.7	97.4	97.8	97.7	97.9	97.9	98.0	98.2	98.1	95.9	96.5
	Kedah													
4.	Alor Setar Airport (Kepala Batas)	94.7	94.3	95.6	96.8	97.4	97.5	97.9	97.8	98.0	98.0	97.8	95.6	96.8
5.	Pulau Langkawi International Airport	90.2	91.8	93.2	95.4	95.7	95.9	96.4	96.0	96.7	96.0	94.5	89.6	94.3
	Kelantan													
6.	Kota Bharu Airport (Pengkalan Chepa)	95.1	95.3	95.7	96.2	95.8	96.0	96.4	96.8	96.9	97.2	97.6	95.6	96.2
7.	Kuala Krai	99.9	99.9	99.9	99.8	99.8	99.8	99.7	99.8	99.8	99.9	99.9	99.9	99.8
	Malacca													
8.	Malacca Airport (Batu Berendam)	95.5	95.4	97.2	98.7	99.0	99.1	99.1	99.2	99.1	99.1	99.0	97.3	98.1
	Pahang													
9.	Batu Embun	98.8	98.3	98.1	98.3	98.7	98.8	98.8	98.7	98.7	98.7	98.9	99.1	98.7
10.	Cameron Highlands (Tanah Rata)	97.5	97.9	98.2	98.6	98.8	98.1	98.7	98.9	99.2	99.0	98.7	98.3	98.5
11.	Kuantan Airport	98.3	98.4	98.7	98.9	99.0	98.9	98.9	98.8	99.1	99.3	99.3	98.8	98.9
12.	Muadzam Shah	96.7	97.2	98.1	98.2	98.2	98.0	98.2	98.2	98.4	98.3	98.5	97.2	97.9
13.	Temerloh	99.1	98.6	98.6	99.0	99.2	99.2	99.2	99.1	99.3	99.3	99.4	99.3	99.1
	Pulau Pinan													
14.	Butterworth Airport	92.5	93.5	96.2	97.2	97.5	96.9	97.2	97.4	98.1	98.4	97.3	92.8	96.3
15.	Penang Internatonal Airport (Bayan Lepas)	93.4	95.4	97.1	98.1	98.1	98.2	98.1	98.2	98.5	98.5	97.3	93.9	97.1
	Perak													
16.	Ipoh Airport	96.2	96.0	96.4	97.1	97.0	96.3	96.4	96.5	97.2	97.7	97.9	97.4	96.8
17.	Sitiawan	99.1	98.9	99.0	99.0	98.9	98.8	98.7	98.8	99.1	99.1	99.3	99.3	99.0
	Perlis													
18.	Chuping	91.9	92.6	95.1	98.1	99.2	99.3	99.4	99.3	99.3	99.3	97.8	94.2	97.1
	Selangor													
19.	Kuala Lumpur International Airport (Subang)	98.3	97.9	98.0	98.3	97.9	97.6	97.5	97.4	97.9	98.2	98.5	98.5	98.0
20.	Petaling Jaya	95.4	95.1	95.5	96.1	95.4	94.4	94.7	94.0	95.2	95.8	96.6	96.0	95.3
	Terengganu													
21.	Kuala Terengganu Airport	95.2	96.5	96.3	97.6	97.5	97.5	97.3	97.6	97.7	98.1	97.8	94.5	97.0
21'	Kajiklim Utama Kuala Terengganu	96.7	97.1	97.3	97.7	97.7	97.7	97.5	97.8	98.0	98.6	98.7	96.9	97.6
SABAH AND SARAWAK														
	Sabah													
22.	Kota Kinabalu International Airport	94.2	93.9	92.8	92.7	93.4	93.3	93.0	92.8	93.6	94.1	94.6	94.0	93.5
23.	Kudat Airport	95.0	94.7	93.7	94.7	95.5	96.9	97.2	97.1	97.3	97.3	97.5	96.3	96.1
24.	Sandakan Airport	96.6	96.3	96.4	97.2	97.5	97.5	97.7	97.5	98.0	97.8	98.0	97.5	97.3
25.	Tawau Airport	97.2	97.1	97.2	97.1	96.9	97.3	97.4	97.3	97.1	96.8	97.3	97.1	97.1
	Sarawak													
26.	Bintulu Airport	98.1	97.9	97.8	98.1	97.9	97.8	97.9	97.7	97.7	97.8	98.1	98.2	97.9
27.	Kuching International Airport	97.9	97.8	97.6	97.7	97.4	97.1	96.9	96.9	97.1	97.6	98.1	98.0	97.5
28.	Miri Airport	98.1	98.0	97.6	97.8	97.6	97.5	97.5	97.4	97.6	97.9	98.2	98.3	97.8
29.	Sibu Airport	99.5	99.5	99.5	99.3	99.2	99.1	99.1	99.1	99.3	99.1	99.3	99.4	99.3
30.	Sri Aman Airport	99.1	98.8	98.8	98.7	98.7	98.3	98.3	98.1	98.4	98.6	98.8	98.8	98.6
	Labuan													
31.	Labuan Airport	95.3	95.8	95.5	95.5	95.8	95.5	95.6	95.7	95.9	96.2	96.3	95.3	95.7

Table D.4 Relative Humidity of the Principal Meteorological Stations (3/3)
- Monthly Average of Daily Minimum Relative Humidity

(Unit: %)

NO. STATION NAME	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
PENINSULAR MALAYSIA													
Johor													
1. Johor Baru International Airport (Senai)	61.9	56.3	57.4	59.7	61.9	60.9	62.3	62.0	61.4	60.7	64.0	66.3	61.2
2. Kluang	64.3	58.7	57.4	60.4	62.4	62.3	63.3	62.6	62.4	61.8	65.5	68.3	62.5
3. Mersing	72.3	70.3	67.9	66.5	65.8	65.6	65.3	65.0	65.1	65.8	71.1	75.1	68.0
Kedah													
4. Alor Setar Airport (Kepala Batas)	47.7	42.9	46.3	55.2	63.5	64.5	64.1	63.3	65.7	64.9	62.9	57.6	58.2
5. Pulau Langkawi International Airport	49.7	48.0	52.7	61.5	67.9	66.9	68.0	69.3	69.5	69.1	63.7	56.3	61.9
Kelantan													
6. Kota Bharu Airport (Pengkalan Chepa)	65.1	61.7	59.9	58.1	58.5	58.7	58.9	59.7	60.6	64.0	70.1	69.9	62.1
7. Kuala Krai	64.1	53.8	54.0	52.7	57.8	57.1	57.6	59.5	60.3	61.5	67.8	69.9	59.7
Malacca													
8. Malacca Airport (Batu Berendam)	54.6	50.6	53.7	59.2	62.0	61.9	62.1	62.4	62.3	61.0	62.6	60.3	59.4
Pahang													
9. Batu Embun	60.7	52.6	52.8	53.3	57.8	57.9	57.8	57.1	57.9	59.3	63.1	66.0	58.0
10. Cameron Highlands (Tanah Rata)	69.2	65.7	66.4	70.1	73.0	69.4	70.5	72.8	74.2	73.8	75.5	74.5	71.3
11. Kuantan Airport	64.1	60.0	59.7	58.9	59.0	58.2	57.6	56.8	57.8	59.9	67.0	70.4	60.8
12. Muadzam Shah	65.3	58.9	61.1	58.2	59.3	58.1	57.3	56.5	57.9	58.9	64.9	69.1	60.5
13. Temerloh	59.4	53.2	53.1	55.6	58.0	57.7	56.7	55.3	57.6	58.1	62.7	64.6	57.7
Pulau Pinan													
14. Butterworth Airport	51.4	53.5	57.2	61.4	63.1	60.6	60.5	61.4	65.0	65.5	62.9	54.9	59.8
15. Penang Internatonal Airport (Bayan Lepas)	54.1	54.5	57.8	62.9	64.9	63.4	63.1	63.8	66.1	66.2	63.9	58.8	61.6
Perak													
16. Ipoh Airport	50.0	47.8	49.9	54.4	55.5	52.9	52.2	52.2	54.6	56.3	57.7	56.1	53.3
17. Sitiawan	59.8	57.9	59.0	61.5	61.5	59.6	58.5	58.6	60.9	62.9	64.4	62.6	60.6
Perlis													
18. Chuping	50.5	44.4	47.1	55.6	63.8	63.4	63.7	64.1	65.5	65.2	65.1	60.8	59.1
Selangor													
19. Kuala Lumpur International Airport (Subang)	52.6	50.2	52.1	56.3	57.7	56.1	56.2	54.9	57.3	57.8	60.1	57.8	55.7
20. Petaling Jaya	50.8	49.6	51.5	54.9	56.1	54.4	54.8	53.8	56.0	56.6	58.8	55.2	54.4
Terengganu													
21. Kuala Terengganu Airport	68.1	64.3	64.3	62.2	62.1	60.9	60.1	61.6	62.3	65.0	69.4	69.5	64.1
21' Kajiklim Utama Kuala Terengganu	70.1	68.2	66.2	64.9	63.9	64.2	64.0	64.4	65.0	67.5	73.3	73.9	67.1
SABAH AND SARAWAK													
Sabah													
22. Kota Kinabalu International Airport	66.7	65.3	63.5	64.5	65.0	62.5	62.9	62.9	64.7	66.3	67.1	65.7	64.7
23. Kudat Airport	72.4	70.0	65.3	62.1	59.9	58.2	59.4	58.4	60.8	64.0	68.3	71.3	64.2
24. Sandakan Airport	70.0	68.3	64.1	61.3	59.5	59.7	59.1	58.3	60.6	61.9	65.8	69.5	63.2
25. Tawau Airport	63.1	62.1	60.5	62.0	62.7	64.7	65.0	64.5	63.0	62.4	62.5	62.2	62.9
Sarawak													
26. Bintulu Airport	70.7	69.9	68.3	66.0	64.9	62.9	62.8	63.0	64.0	65.8	66.6	68.2	66.1
27. Kuching International Airport	67.6	65.4	62.1	59.3	57.7	56.6	56.1	56.4	57.6	58.9	60.5	64.9	60.3
28. Miri Airport	67.7	66.4	64.9	65.1	64.2	62.5	62.3	62.0	63.7	65.7	66.8	67.2	64.9
29. Sibu Airport	69.5	62.9	60.6	58.7	57.9	56.9	56.2	56.6	58.7	59.0	60.4	63.3	60.1
30. Sri Aman Airport	64.7	61.2	60.4	50.6	61.0	57.4	58.5	58.2	59.3	59.9	61.4	63.4	60.5
Labuan													
31. Labuan Airport	68.2	66.4	61.4	61.5	64.4	62.4	62.5	61.8	63.7	65.3	66.5	66.3	64.2

Table D.5 Monthly and Annual Average Rainfall of the Principal Meteorological Stations (1/2)

(Unit : mm)

NO.	STATION NAME	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
	PENINSULAR MALAYSIA													
	Johor													
1.	Johor Baru International Airport (Senai)	162.4	119.0	209.0	230.5	212.6	142.8	191.3	161.9	210.1	237.0	252.7	266.9	2396.2
2.	Kluang	134.8	109.6	183.9	221.4	190.2	137.8	146.4	130.7	177.2	185.9	220.5	254.3	2092.7
3.	Mersing	322.0	139.0	141.7	120.6	142.2	139.3	165.1	169.9	175.8	201.2	365.8	641.4	2724.0
	Kedah													
4.	Alor Setar Airport (Kepala Batas)	34.7	54.3	111.8	193.1	235.7	165.4	201.0	204.5	288.3	294.9	210.9	83.4	2078.0
5.	Pulau Langkawi International Airport	16.8	24.5	70.2	213.6	217.9	234.2	326.5	230.3	387.8	324.0	165.7	31.2	2242.6
	Kelantan													
6.	Kota Bharu Airport (Pengkalan Chepa)	145.8	53.5	94.5	90.1	110.5	129.2	152.8	164.7	194.6	280.9	641.0	547.2	2604.8
7.	Kuala Krai	116.5	48.7	95.6	90.5	108.2	156.3	173.0	154.7	254.9	234.6	480.3	404.6	2318.0
	Malacca													
8.	Malacca Airport (Batu Berendam)	87.2	99.8	146.8	193.1	171.2	170.6	174.2	171.6	207.3	211.9	236.9	140.8	2011.4
	Pahang													
9.	Batu Embun	130.2	118.6	139.5	187.1	186.4	113.9	147.7	139.4	231.7	233.9	286.8	241.5	2156.6
10.	Cameron Highlands (Tanah Rata)	111.4	110.0	190.3	270.4	282.0	140.0	164.9	177.8	253.2	337.4	300.0	198.1	2535.5
11.	Kuantan Airport	311.2	149.7	175.5	166.9	192.6	161.6	158.1	179.2	231.1	274.0	355.2	594.1	2949.4
12.	Muadzam Shah	260.3	117.2	257.4	192.5	154.4	115.9	157.0	112.7	168.7	234.4	280.3	406.3	2457.1
13.	Temerloh	106.7	93.1	157.9	163.5	177.9	104.0	125.3	135.9	185.9	199.8	243.5	181.9	1875.4
	Pulau Pinan													
14.	Butterworth Airport	61.5	69.6	113.2	209.1	219.8	145.6	181.9	212.8	343.1	328.7	210.6	90.3	2186.2
15.	Penang Internatonal Airport (Bayan Lepas)	67.8	89.5	141.8	211.3	242.4	175.7	210.0	237.2	345.0	376.3	237.3	105.2	2439.3
	Perak													
16.	Ipoh Airport	148.6	141.8	184.6	258.0	228.0	138.7	160.1	148.9	203.2	300.5	280.7	235.6	2428.7
17.	Sitiawan	141.3	134.6	125.4	164.7	111.8	80.9	105.2	108.3	168.4	207.1	225.5	198.3	1777.9

Table D.5 Monthly and Annual Average Rainfall of the Principal Meteorological Stations (2/2)

(Unit : mm)

NO.	STATION NAME	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
	Perlis													
18.	Chuping	13.1	44.1	96.5	178.8	197.3	115.5	180.1	182.4	223.9	237.1	185.3	69.6	1723.0
	Selangor													
19.	Kuala Lumpur International Airport (Subang)	161.1	157.4	228.0	276.6	208.9	125.4	119.9	141.6	187.4	254.4	269.0	246.0	2375.7
20.	Petaling Jaya	171.6	184.6	239.6	290.9	245.3	121.9	131.5	160.6	195.1	269.0	302.5	254.2	2566.8
	Terengganu													
21.	Kuala Terengganu Airport	136.1	43.2	133.1	97.4	106.3	103.2	77.8	121.9	203.5	246.8	757.5	404.9	2431.6
21'	Kajiklim Utama Kuala Terengganu	160.0	87.9	108.1	97.9	105.1	107.6	104.4	142.6	179.2	254.5	661.8	551.8	2561.0
SABAH AND SARAWAK														
	Sabah													
22.	Kota Kinabalu International Airport	120.3	61.8	63.6	115.6	225.5	301.2	281.5	260.3	313.1	336.7	302.2	229.6	2611.4
23.	Kudat Airport	340.1	142.2	71.7	51.6	108.5	103.3	113.9	133.2	133.7	190.1	301.2	389.5	2079.0
24.	Sandakan Airport	426.4	255.0	163.4	107.2	133.8	193.4	195.2	229.8	235.1	257.6	341.7	469.5	3008.2
25.	Tawau Airport	127.5	100.1	87.0	98.3	132.2	174.1	195.2	214.0	172.8	169.9	153.4	147.9	1772.4
	Sarawak													
26.	Bintulu Airport	401.4	256.5	256.3	244.5	238.6	254.0	254.9	273.9	308.5	344.9	410.7	449.6	3693.6
27.	Kuching International Airport	683.7	494.3	336.2	278.8	248.7	197.2	200.0	209.6	273.8	333.5	353.1	476.8	4085.9
28.	Miri Airport	294.5	155.5	138.9	170.5	196.1	233.1	197.7	205.3	269.6	317.0	324.1	334.4	2836.8
29.	Sibu Airport	376.0	254.3	302.6	271.4	227.0	176.3	181.8	213.3	270.7	273.4	297.2	372.9	3216.9
30.	Sri Aman Airport	406.1	156.2	283.3	258.9	269.7	205.2	216.8	199.2	281.7	290.4	370.8	370.3	3308.7
	Labuan													
31.	Labuan Airport	221.5	107.5	123.0	198.8	312.8	295.4	290.4	288.8	361.6	409.0	391.6	299.1	3299.5

Table D.6 Number of Monthly and Annual Average Rainy Days of the Principal Meteorological Stations

(Unit: days)

NO.	STATION NAME	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
	PENINSULAR MALAYSIA													
	Johor													
1.	Johor Baru International Airport (Senai)	13	11	16	19	18	15	17	15	18	20	21	19	202
2.	Kluang	11	9	13	18	17	14	16	15	17	18	19	17	184
3.	Mersing	16	11	11	12	14	14	15	15	16	17	22	23	187
	Kedah													
4.	Alor Setar Airport (Kepala Batas)	4	5	9	15	18	15	17	17	20	22	18	9	169
5.	Pulau Langkawi International Airport	2	3	9	15	20	15	21	17	22	22	14	6	166
	Kelantan													
6.	Kota Bharu Airport (Pengkalan Chepa)	13	7	7	7	11	11	13	15	16	20	22	20	163
7.	Kuala Krai	15	7	11	10	13	12	13	17	19	20	22	22	182
	Malacca													
8.	Malacca Airport (Batu Berendam)	9	10	13	16	15	13	15	16	15	18	19	15	175
	Pahang													
9.	Batu Embun	17	11	13	14	15	10	13	13	18	19	20	22	186
10.	Cameron Highlands (Tanah Rata)	13	12	17	20	22	15	16	18	22	25	24	20	225
11.	Kuantan Airport	16	12	11	14	15	12	13	15	17	20	22	22	190
12.	Muadzam Shah	16	11	15	16	14	11	14	13	16	19	20	20	183
13.	Temerloh	14	9	11	14	15	9	13	11	16	17	18	18	165
	Pulau Pinan													
14.	Butterworth Airport	6	8	11	16	18	13	15	16	21	22	18	12	175
15.	Penang Internatonal Airport (Bayan Lepas)	7	8	12	17	18	13	15	16	20	22	19	12	180
	Perak													
16.	Ipoh Airport	12	12	14	18	17	12	13	14	19	21	21	18	191
17.	Sitiawan	12	12	13	15	13	9	11	12	16	19	20	17	169
	Perlis													
18.	Chuping	3	4	8	14	17	14	15	16	21	21	17	9	160
	Selangor													
19.	Kuala Lumpur International Airport (Subang)	14	13	17	20	16	12	13	14	16	20	22	19	195
20.	Petaling Jaya	14	14	19	20	17	11	13	13	17	20	22	18	198
	Terengganu													
21.	Kuala Terengganu Airport	17	8	9	9	10	11	10	13	17	19	24	21	168
21'	Kajiklim Utama Kuala Terengganu	16	10	9	9	11	11	11	14	15	19	23	23	171
	SABAH AND SARAWAK													
	Sabah													
22.	Kota Kinabalu International Airport	12	9	8	11	17	16	17	16	19	20	19	17	181
23.	Kudat Airport	16	10	7	5	9	11	11	11	11	16	20	19	147
24.	Sandakan Airport	21	15	12	9	12	14	14	15	16	18	21	23	190
25.	Tawau Airport	12	10	9	10	12	13	14	13	12	12	13	13	144
	Sarawak													
26.	Bintulu Airport	21	16	18	17	17	14	16	17	18	21	21	24	221
27.	Kuching International Airport	25	21	20	20	19	17	16	17	19	23	24	25	247
28.	Miri Airport	18	13	13	14	16	14	15	15	18	21	21	21	198
29.	Sibu Airport	23	18	20	19	19	14	16	17	18	21	22	24	230
30.	Sri Aman Airport	23	17	20	19	18	13	16	14	19	20	24	23	227
	Labuan													
31.	Labuan Airport	13	10	10	14	18	16	16	15	18	21	21	17	190

Table D.7 Recorded Maximum 1 Day Rainfalls and Their Occurrence Dates of the Principal Meteorological Stations

NO.	STATION NAME	MAX. RAINFALL (mm)	DATE
PENINSULAR MALAYSIA			
	Johor		
1.	Johor Baru International Airport (Senai)	364.4	Dec. 02, 1978
2.	Kluang	194.4	Dec. 25, 1983
3.	Mersing	430.0	Jan. 02, 1971
	Kedah		
4.	Alor Setar Airport (Kepala Batas)	178.8	Sep. 18, 1971
5.	Pulau Langkawi International Airport	205.9	Sep. 17, 1990
	Kelantan		
6.	Kota Bharu Airport (Pengkalan Chepa)	608.1	Jan. 06, 1967
7.	Kuala Krai	356.0	Nov. 20, 1988
	Malacca		
8.	Malacca Airport (Batu Berendam)	275.2	Jun. 06, 1979
	Pahang		
9.	Batu Embun	160.8	Apr. 11, 1990
10.	Cameron Highlands (Tanah Rata)	123.2	Apr. 24, 1974
11.	Kuantan Airport	527.5	Nov. 24, 1975
12.	Muadzam Shah	285.8	Dec. 07, 1987
13.	Temerloh	200.1	Aug. 12, 1987
	Pulau Pinan		
14.	Butterworth Airport	218.8	Sep. 17, 1976
15.	Penang Internatonal Airport (Bayan Lepas)	257.5	Nov. 09, 1964
	Perak		
16.	Ipoh Airport	152.1	Mar. 31, 1965
17.	Sitiawan	178.7	Sep. 28, 1976
	Perlis		
18.	Chuping	155.1	Nov. 20, 1988
	Selangor		
19.	Kuala Lumpur International Airport (Subang)	171.5	Jan. 04, 1971
20.	Petaling Jaya	132.9	Oct. 11, 1991
	Terengganu		
21.	Kuala Terengganu Airport	329.9	Nov. 04, 1988
21'	Kajiklim Utama Kuala Terengganu	471.2	Nov. 27, 1959
SABAH AND SARAWAK			
	Sabah		
22.	Kota Kinabalu International Airport	260.2	Aug. 29, 1976
23.	Kudat Airport	207.2	Dec. 27, 1983
24.	Sandakan Airport	464.6	Dec. 27, 1973
25.	Tawau Airport	155.6	Oct. 29, 1989
	Sarawak		
26.	Bintulu Airport	325.4	Feb. 08, 1971
27.	Kuching International Airport	414.0	Feb. 02, 1964
28.	Miri Airport	304.0	Jan. 12, 1963
29.	Sibu Airport	209.6	Sep. 28, 1984
30.	Sri Aman Airport	150.7	Sep. 28, 1986
	Labuan		
31.	Labuan Airport	185.2	Nov. 25, 1991

Table D.8 Mean Daily Evaporation of the Principal Meteorological Stations

(Unit: mm/day)

NO.	STATION NAME	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
PENINSULAR MALAYSIA														
	Johor													
1.	Johor Baru International Airport (Senai)	3.6	4.0	3.8	3.6	3.3	3.4	3.2	3.3	3.2	3.2	2.9	3.0	3.4
2.	Kluang	3.3	3.8	3.6	3.3	2.9	2.9	2.8	2.9	2.9	2.9	2.7	2.8	3.1
3.	Mersing	4.1	4.7	4.6	4.2	3.8	3.7	3.6	3.8	3.8	3.6	3.3	3.6	3.9
	Kedah													
4.	Alor Setar Airport (Kepala Batas)	5.4	6.0	5.7	5.0	4.0	3.6	3.6	3.6	3.6	3.6	3.5	4.3	4.3
5.	Pulau Langkawi International Airport	7.1	6.7	6.0	5.1	3.7	4.0	3.6	3.9	3.5	3.4	4.4	6.0	4.8
	Kelantan													
6.	Kota Bharu Airport (Pengkalan Chepa)	4.4	5.0	5.3	5.5	5.0	4.5	4.6	4.5	4.5	4.2	3.5	3.7	4.5
7.	Kuala Krai	2.7	3.8	4.2	4.4	4.0	3.8	4.0	3.7	3.6	3.2	2.5	2.2	3.5
	Malacca													
8.	Malacca Airport (Batu Berendam)	5.1	5.6	5.2	4.6	4.2	4.0	3.9	4.0	4.2	4.3	3.9	4.2	4.4
	Pahang													
9.	Batu Embun	2.5	3.4	3.8	3.9	3.5	3.3	3.2	3.3	3.4	3.1	2.7	2.1	3.2
10.	Cameron Highlands (Tanah Rata)	2.1	2.4	2.5	2.2	2.0	2.1	2.0	2.0	1.8	1.7	1.5	1.7	2.0
11.	Kuantan Airport	3.2	3.8	4.2	4.1	4.1	3.9	4.0	4.1	4.1	3.7	2.9	2.9	3.7
12.	Muadzam Shah	3.4	4.0	3.8	3.8	3.5	3.5	3.5	3.6	3.6	3.5	2.8	2.8	3.5
13.	Temerloh	3.1	3.8	4.0	3.8	3.6	3.4	3.4	3.5	3.5	3.3	2.9	2.6	3.4
	Pulau Pinan													
14.	Butterworth Airport	-	-	-	-	-	-	-	-	-	-	-	-	
15.	Penang Internatonal Airport (Bayan Lepas)	5.0	5.0	4.7	4.3	3.8	3.9	3.8	3.7	3.5	3.4	3.6	4.4	4.1
	Perak													
16.	Ipoh Airport	4.2	4.5	4.5	4.5	4.0	4.1	4.0	4.1	3.8	4.0	3.5	3.8	4.1
17.	Sitiawan	3.5	4.0	4.1	4.0	3.8	3.6	3.8	3.7	3.7	3.5	3.2	3.3	3.7
	Perlis													
18.	Chuping	4.7	5.5	5.1	4.5	3.6	3.1	3.1	3.2	3.1	2.8	2.8	3.5	3.7
	Selangor													
19.	Kuala Lumpur International Airport (Subang)	4.3	5.0	5.1	4.8	4.5	4.4	4.3	4.5	4.3	4.3	3.9	3.7	4.4
20.	Petaling Jaya	3.4	3.9	3.9	3.8	3.5	3.3	3.3	3.5	3.3	3.3	3.0	2.9	3.4
	Terengganu													
21.	Kuala Terengganu Airport	4.2	4.9	5.1	5.3	4.8	4.5	4.4	4.3	4.4	3.9	3.7	3.9	4.4
21'	Kajiklim Utama Kuala Terengganu	3.7	4.2	4.7	4.7	4.4	4.1	4.0	4.0	3.8	3.5	3.1	3.2	3.9
SABAH AND SARAWAK														
	Sabah													
22.	Kota Kinabalu International Airport	4.4	4.7	5.2	5.4	5.2	5.1	5.0	5.0	4.9	4.8	4.6	4.5	4.9
23.	Kudat Airport	3.8	4.3	5.1	5.4	5.1	4.7	4.5	4.7	4.5	4.3	3.6	3.6	4.5
24.	Sandakan Airport	4.2	4.8	5.4	5.6	5.2	4.8	4.6	4.8	4.5	4.3	3.9	3.8	4.7
25.	Tawau Airport	3.6	4.0	4.4	4.4	4.2	3.7	3.8	4.1	4.2	4.0	3.8	3.4	3.9
	Sarawak													
26.	Bintulu Airport	3.5	4.0	4.3	4.3	4.2	4.3	4.1	4.2	4.1	3.9	3.7	3.6	4.0
27.	Kuching International Airport	3.1	3.4	3.7	3.9	4.0	4.0	4.0	4.2	3.9	3.8	3.5	3.2	3.7
28.	Miri Airport	3.6	4.2	4.5	4.7	4.5	4.5	4.5	4.6	4.6	4.4	4.1	3.8	4.3
29.	Sibu Airport	3.1	3.4	3.7	3.7	3.8	3.8	3.8	3.8	3.8	3.7	3.5	3.2	3.6
30.	Sri Aman Airport	2.8	3.2	3.4	3.4	3.2	3.4	3.3	3.5	3.3	3.5	3.2	2.9	3.3
	Labuan													
31.	Labuan Airport	4.5	4.8	5.4	5.3	4.8	4.4	4.3	4.7	4.7	4.4	4.4	4.3	4.7

Table D.9 Recorded Maximum Surface Wind of the Principal Meteorological Stations

NO.	STATION NAME	WIND SPEED (m/s)	DIRECTION (deg.)	DATE
	PENINSULAR MALAYSIA			
	Johor			
1.	Johor Baru International Airport (Senai)	27.6	340	Sep., 1981
2.	Kluang	31.6	60	Apr., 1978
3.	Mersing	32.0	170	Aug., 1987
	Kedah			
4.	Alor Setar Airport (Kepala Batas)	28.8	150	Mar., 1984
5.	Pulau Langkawi International Airport	20.6	240	Jul., 1992
	Kelantan			
6.	Kota Bharu Airport (Pengkalan Chepa)	34.8	260	Jul., 1990
7.	Kuala Krai	27.0	300	Sep., 1986
	Malacca			
8.	Malacca Airport (Batu Berendam)	29.6	250	May, 1951
	Pahang			
9.	Batu Embun	24.0	250	Aug., 1986
10.	Cameron Highlands (Tanah Rata)	25.0	300	Oct., 1939
11.	Kuantan Airport	30.0	230	Jun., 1962
12.	Muadzam Shah	21.7	240	Aug., 1985
13.	Temerloh	24.5	310	Oct., 1978
	Pulau Pinan			
14.	Butterworth Airport	25.6	50	Apr., 1988
15.	Penang Internatonal Airport (Bayan Lepas)	27.0	40	Apr., 1988
	Perak			
16.	Ipoh Airport	39.0	330	Mar., 1990
17.	Sitiawan	28.0	100	Apr., 1970
	Perlis			
18.	Chuping	25.3	280	Jun., 1985
	Selangor			
19.	Kuala Lumpur International Airport (Subang)	35.5	300	Mar., 1988
20.	Petaling Jaya	30.8	320	Apr., 1983
	Terengganu			
21.	Kuala Terengganu Airport	30.8	300	Jul., 1985
21'	Kajiklim Utama Kuala Terengganu	26.0	340	Dec., 1988
	SABAH AND SARAWAK			
	Sabah			
22.	Kota Kinabalu International Airport	33.1	240	Aug., 1990
23.	Kudat Airport	27.5	240	Aug., 1990
24.	Sandakan Airport	27.0	150	Nov., 1987
25.	Tawau Airport	24.1	280	Jun., 1981, May., 1988
	Sarawak			
26.	Bintulu Airport	25.6	80	Jul., 1976
27.	Kuching International Airport	41.7	320	Sep., 1992
28.	Miri Airport	30.0	230	Nov., 1990
29.	Sibu Airport	30.0	190	Aug., 1967
30.	Sri Aman Airport	29.2	200	Nov., 1986
	Labuan			
31.	Labuan Airport	26.4	160 and 230	Jun. and Aug., 1953

Table D.10 List of Major Rivers in Malaysia (1/2)

River Name	States	Catchment Area (km2)	Major Cities and Towns
Peninsular Malaysia			
Perlis	Perlis	790	Kangar
Kedah	Kedah	3,695	Alor Setar
Muda	Kedah, Pulau Pinang	4,300	Kuala Muda
Perai	Kedah, Pulau Pinang	895	Kulim, Butterworth
Pinang	Pulau Pinang	300	Georgetown
Kurau	Perak	3,255	-
Perak	Perak	14,700	Ipoh, Kuala Kangsar, Teluk Intan
Bernam	Perak, Selangor	3,335	Tanjung Malim, Sabak Bernam
Selangor	Selangor	1,820	Kuala Selangor
Kelang	Selangor	1,425	Kuala Lumpur, Petaling Jaya, Shah Alam, Kelang
Langat	Selangor	1,815	-
Linggi	Negari Sembilan	1,420	Seremban
Malaka	Malaka	1,010	Melaka
Kasang	Melaka	705	Jasin
Muar	Johor	6,595	Segamat, Bandar Maharani
Batu Pahat	Johor	2,600	Batu Pahat
Pontian Kechil	Johor	2,660	Pontian
Johor	Johor	3,250	Kota Tinggi
Sedili Besar	Johor	1,820	Mawai
Endau	Johor, Pahang	4,740	-
Rompin	Pahang	4,285	Muadzam Shah, Kuala Rompin
Bebar	Pahang	1,895	Nenasi
Pahang	Pahang	29,300	Temerloh, Pekan
Kuantan	Pahang	2,025	Kuantan
Kemaman	Terengganu	2,570	Chukai
Dungun	Terengganu	1,875	Dungun
Terengganu	Terengganu	4,650	Kuala Terengganu, Kuala Berang
Setiu	Terengganu	1,035	-
Besut	Terengganu	1,230	Jerteh
Kamasin	Kelantan	1,020	Bacok
Kelantan	Kelantan	13,100	Kota Bharu

Note : Data Source of catchment area ; National Water Resources Study, Malaysia, JICA, 1982

Table D.10 List of Major Rivers in Malaysia (2/2)

River Name	States	Catchment Area (km2)	Major Cities and Towns
Sabah and Sarawak			
Pensiangan	Sabah	5,971	Sepulot
Serudong	Sabah	1,308	-
Kalabakan	Sabah	1,371	-
Tawau	Sabah	888	Tawau
Kalumpang	Sabah	2,792	Tg. Tutup
Silibukan	Sabah	2,714	-
Segama	Sabah	5,558	-
Kinabatangan	Sabah	16,755	-
Segaliud	Sabah	2,335	Sandakan
Labuk	Sabah	6,829	-
Sugut	Sabah	3,094	Pamoi, Ranau
Paitan	Sabah	1,474	-
Bengkoka	Sabah	1,866	-
Bongan	Sabah	2,126	Bandau
Kadamaian	Sabah	1,336	Kota Belud
Tuaran	Sabah	1,247	Tuaran
Putatan	Sabah	629	Kota Kinabalu
Padas	Sabah	9,180	Keningau, Tenom
Lakutan	Sabah	1,291	-
Lawas	Sarawak	1,080	Lawas
Trusan	Sarawak	2,768	Trusan
Limbang	Sarawak	3,920	Limbang
Baram	Sarawak	22,325	Marudi
Miri	Sarawak	788	Miri
Niah	Sarawak	1,345	-
Buai	Sarawak	1,440	-
Similajau	Sarawak	1,268	Similajau
Kemena	Sarawak	6,000	Bintulu
Tatau	Sarawak	5,150	-
Balingian	Sarawak	2,518	Balingian
Mukah	Sarawak	2,625	Mukah
Oya	Sarawak	2,005	-
Rajang	Sarawak	51,053	Sibu, Belaga, Kapit
Kerian	Sarawak	1,675	-
Saribas	Sarawak	1,900	Betong
Lupar	Sarawak	6,813	Bandar Sri Aman
Sadong	Sarawak	3,645	Serian
Sarawak	Sarawak	3,358	Kuching
Kayan	Sarawak	1,838	Lundu

Note : Data Source of catchment area ; National Water Resources Study, Malaysia, JICA, 1982

Table D.11 Record of Disasters of Major Floods

Year	Affected Areas
1926	The biggest floods which struck the whole of Peninsular Malaysia
1931	Areas surrounding the borders of Perak-Kelantan and Kinta Vallay, Perak
1947	North Perak including Krian District
1954	A vast area in Johor and coastal areas of Terengganu
1957	Klang Valley, Selangor. Although the affected area did not cover a big portion of the Kelang Valley but the flood had destroyed a huge amount of valuables because of the high population in the area.
1967	The Kelantan River, Terengganu river and the Perak River. The worst flood tragedy ever occurred in these areas. North and west areas of Sarawak.
1971	A high number of valuables and properties were destroyed in many places in Peninsular Malaysia. Among the areas where the highest amount of valuables destroyed were ; i) Pahang river basin ii) City of Kuala Lumpur In Sarawak, the affected areas were the middle and western areas.
1973	Pahang river, Kuantan river and the whole of the Terengganu and Kelantan rivers
1979	Major floods in Pahang, Terengganu and Johor
1981	Sabah especially in the Kinabatangan river
1983	Major floods in Pahang, Terengganu, Kelantan and Johor
1986	Major floods in Kelantan and Terengganu
1988	Major floods in Kedah, Pahang, Terengganu and Kelantan

Table D.12 List of Existing Major Studies for Rivers and Urban Drainage in Malaysia (1/2)

RIVER	YEAR	AGENCY/CONSULTANT
KUALA LUMPUR	1978	SINCLAIR AND KNIGHT
CUKAI	1978	JPT
RAUB	1979	PERUNDNG BAKTI
BUTTERWORTH/BKT MERTAJAM	1979	JICA
ALOR SETAR	1981	JICA
SANDAKAN/TAWAU/KOTA KINABALU	1981	ENG. SCIENCE INC.
KUANTAN/KUANTAN PORT	1982	MINCO/ENG. SCIENCE INC.
MELAKA	1982	ANGKASA/GHD
SEREMBAN	1982	EEC
JOHOR BAHRU	1982	BUMI WATSON
BINTULU	1982	EEC
KELANG	1982	JICA
KOTA BHARU	1983	MINCO
K. TERENGGANU	1983	SMHB
KERTIH/KEMASIN	1985	SMHB
PORT DICSON	1986	MINCO
MUAR	1988	ABU BAKAR ASSOCIATES
TELUK INTAN	1991	RANHILL BERSEKUTU
LABUAN	1992	KTA SARAWAK
KULIM	in progress	ERICO
CHUKAI	in progress	ZAABA
LANGKAWI	in progress	
BATU PAHAT	in progress	A.I. ASSOCIATES
MIRI	in progress	KTA SARAWAK
SIBU	in progress	KTA SARAWAK
SG. PETANI	in progress	PERUNDING BAKTI

Table D.12 List of Existing Major Studies for Rivers and Urban Drainage in Malaysia (2/2)

RIVER	YEAR	AGENCY/CONSULTANT
PAHANG	1973	AUSTRALIA ENG. CONSULTANTS
LIMBANG	1976	M&R INTERNATIONAL
KELANTAN	1977	TONKIN & TAYLOR/ENEX
KINABATANGAN	1977	JICA
TERENGGANU	1978	SSP/SMEC
SAMARAHAN	1982	KTA/CSF
ALL OVER MALAYSIA	1982	JICA
LOWER PERAK	1983	JICA
BATU PAHAT	1985	SSP/SMEC
GOLOK	1985	SMEC/McGOWEN
JOHOR	1985	JICA
BESUT	1988	KTA
KRIAN	1988	SMHB
KELANG	1989	JICA
KELANTAN	1989	JICA
KURAU	-	MACE

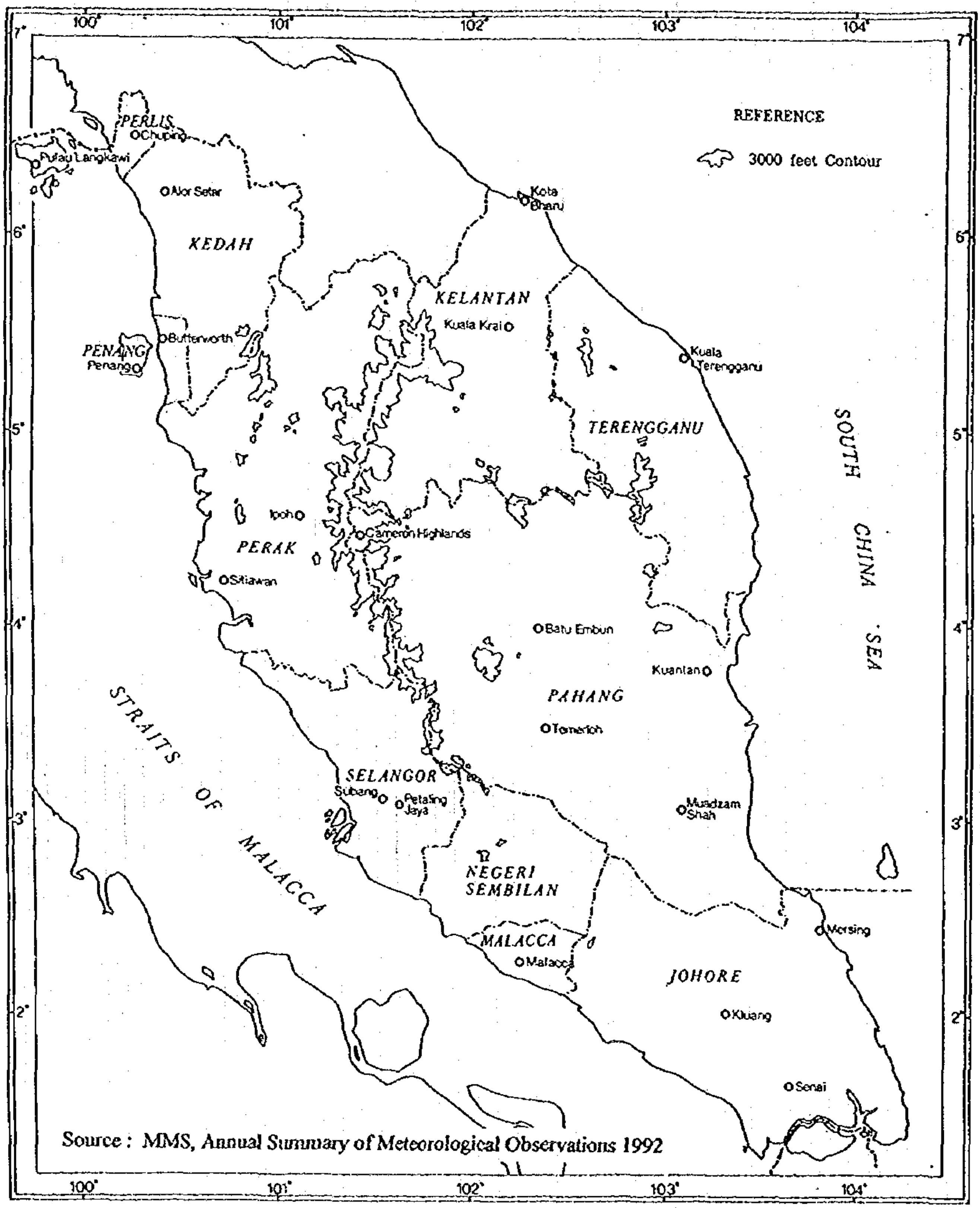


Figure D.1 Locations of Principal Meteorological Stations in Malaysia (1/2)

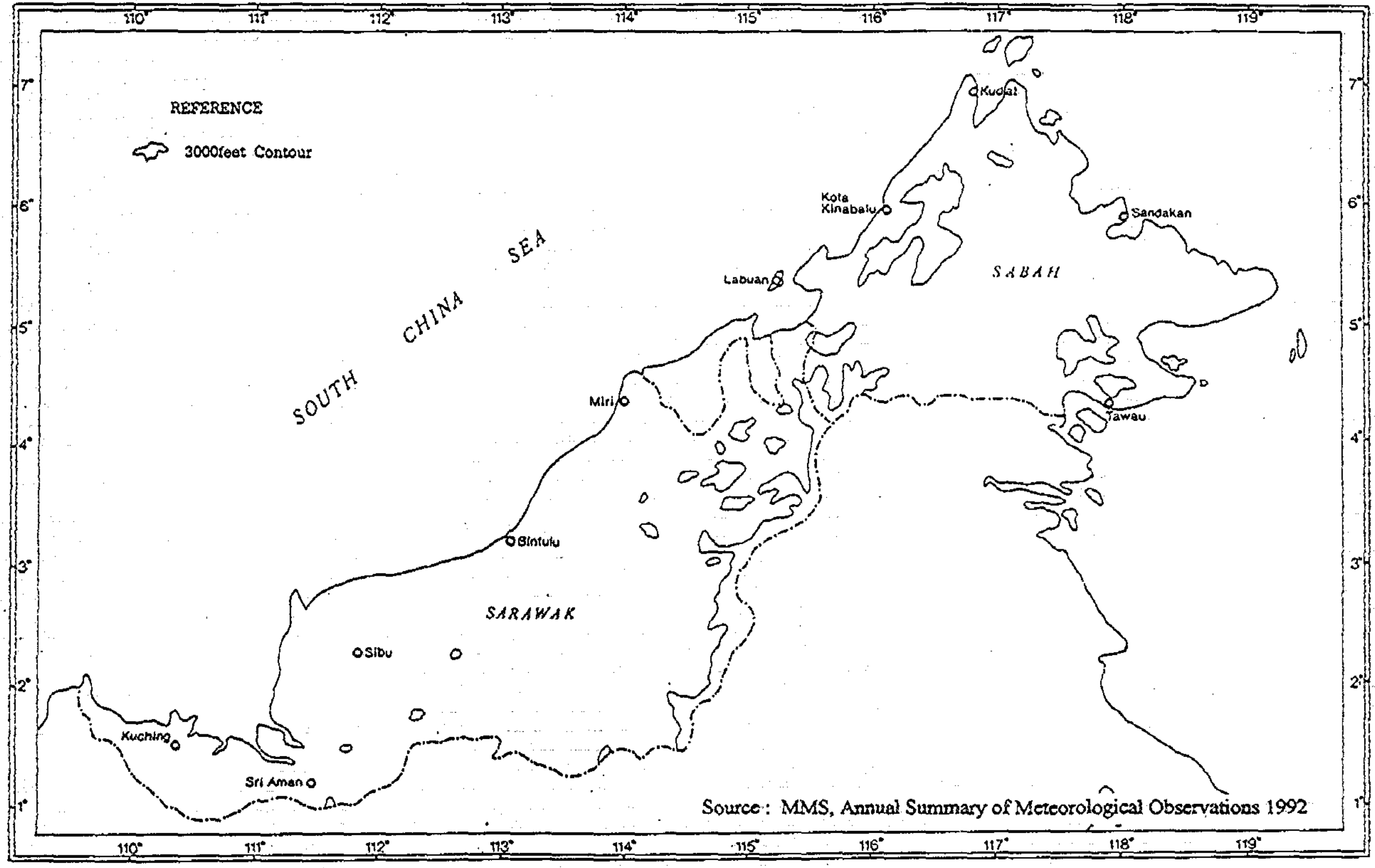


Figure D.1 Locations of Principal Meteorological Stations in Malaysia (2/2)

APPENDIX E

BRIDGE SITE SURVEY

1. Itinerary of Survey Trip

First Survey in West Coast of Peninsula Northward in September 1 to 4, 1994.

September 1:	Kuala Lumpur to Ipoh along Route 1 with bridge surveying .Overnight at Ipoh.
September 2:	Visit JKR state office at Ipoh and move to Penang along Route 1 with bridge surveying. Overnight at Penang.
September 3:	Visit JKR state office at Penang and inspect bridges in Pulau Penang and Kedah. Overnight at Penang.
September 4:	Penang to Kuala Lumpur with a bridge survey stop.

Second Survey in West Coast of Peninsular Southward in September 8 to 10, 1994.

September 8:	Kuala Lumpur to Melaka with bridge surveys along Route 1 from Alor Gajah to Segamat and Route 23 from Segamat to Tangkak. Overnight at Melaka.
September 9:	Melaka to Johor Bahru along Route 5 with bridge surveying. Overnight at Johor Bahru.
September 10:	Visit JKR state office at Johor Bahru and go back to Kuala Lumpur with several bridge survey stops.

Third Survey in East Coast of Peninsular in North Half and Sarawak/Sabah in September 14 to 25, 1994

September 14:	Kuala Lumpur to Kuantan with bridge surveys along Route 2. Overnight at Kuantan.
September 15:	Visit JKR state office at Kuantan and move to Kuala Trengganu with bridge surveys along Route 3. Overnight at Kuala Trengganu.
September 16:	Kuala Trenggnu to Kota Bahru with bridge surveys along Route 3. Overnight at Kota Bahru.
September 17:	Visit JKR state office at Kota Bahru and a bridge site in the city. Overnight at Kota Bahru.
September 18:	Fly to Kuching via Kuala Lumpur. Overnight at Kuching.
September 19:	Bridge surveying around Kuching. Overnight at Kuching.

September 20: Bridge surveying in and around Kuching. Overnight at Kuching.

September 21: Fly to Bintulu and drive to Miri with bridge surveys. Overnight at Miri.

September 22: After a bridge survey at Miri, fly to Kota Kinabalu and visit JKR state office, Council of Japan and Japan Overseas Cooperation Volunteers Office. Overnight at Kota Kinabalu.

September 23: Bridge surveying around Kota Kinabalu. Overnight at Kota Kinabalu.

September 24: Kota Kinabalu to Sandakan with bridge surveys. Overnight at Sandakan.

September 25: Fly back to Kuala Lumpur via Kota Kinabalu and Miri.

Table E.1 List of Inspected Bridges (1/2)

	FT Route No.	No.	Crossing	District	State etc.	Construct. Year	Type of Super-str.	Total Length (m)	Span	
									No.	Max (m)
1	1	481/70	Sg. Behrang	Bat. Padang	Perak	1969	SG	49.2	4	11.92
2	1	498/20	Sg. Trolak	Bat. Padang	Perak	1963	SG	37.27	3	12.08
3	1	509/80	Sg. Keruit	Bat. Padang	Perak	1941	SG	7	1	6.53
4	1	522/80	Sg. Tengor	Bat. Padang	Perak	1990	SG	30	1	24.3
5	1	528/70	Sg. Gedong	Bat. Padang	Perak	1970	SG	32.24	1	30.7
6	1	539/50	SG. Bt. Padang	Bat.Padang	Perak	1991	SG	63.2	3	24.4
7	1	548/80	Sg.Silo	Bat. Padang	Perak	1974	SG	25.24	1	- 18.7
8	1	564/50	Sg. Kampar	Kinta	Perak	1972	SG	41.13	3	41.13
9	1	580/90	Sg. Tekah	Kinta	Perak	1967	SG	18.37	3	8
10	1	589/80	River	Kinta	Perak	1960	BC	5.5	3	1.83
11	1	622/10	River	Laut M&S	Perak	-	SG	10	1	-
12	1	662/40	River	Laut M&S	Perak	-	SG	10	1	-
13	1	677/10	River	Laut M&S	Perak	1992	SG	36.4	1	30.8
14	1	686/80	Sg. Sepetang	Laut M&S	Perak	1950	CT	106.4	5	21
15	1	696/90	Sg. Kurau	Krien	Perak	1985	CT	118	3	43.3
16	1	750/80	Railway	S. Prai T	P. Pinang	1969	SG	59.44	6	11.25
17	1	757/00	Sg. Perai	S. Prai T	P. Pinang	1965	SG	218.03	7	31.29
18	1	782/10	Sg. Muda	S. Prai Utara	P.Pinang	1954	AR	273.14	3	57.32
19	1	783/80	Irrigation canal	Kuala Muda	Kedah	1925	FR	14.7	2	7.35
20	1	803/30	Sg. Lalang	Kuala Muda	Kedah	1992	SG	36.5	1	30.8
21	1	807/00	Sg. Bongkok	Kuala Muda	Kedah	1957	CT	38	5	12.2
22	1	814/50	Railway	Kuala Muda	Kedah	1977	SG	32.2	1	30.3
23	1	820/40	River	Kuala Muda	Kedah	1970	SG	14.6	1	11.8
24	6	14/10	Sg. Ara	Timor Laut	P. Pinang	1985	SG	21	5	12.2
25	6	017/50	Road	Barat Daya	P. Pinang	1985	SG	429.44	17	30.74
26	1	072/90	River	Kluang	Johor	1930	SG	12.2	1	12
27	1	081/0.5	SG. Macap	Kluang	Johor	1954	CG	27.4	3	15.9
28	1	185/40	Sg. Segamat	Segamat	Johor	1960	CT	76.87	3	33.53
29	1	197/80	Sg. Merlimed	Segamat	Johor	1970	SG	45.72	3	14.64
30	1	202/50	River	Segamat	Johor	1982	SG	38.43	3	18.13
31	1	226/10	River	Tampin	Melaka	1964	SG	35.52	3	11.09
32	5	025/20	Spillway (Pulai)	Johor Bahru	Johor	1940	CG	20.87	3	12.61
33	5	056/90	Sg. Pontian Besar	Pontian	Johor	1966	SG	72.54	6	11.87
34	5	085/50	Tempok Main Dr.	Batu Pahat	Johor	1970	SG	50.76	3	17.75
35	5	92/10	Sg. Rengit	Batu Pahat	Johor	1960	BC	21.7	5	2.7
36	5	105/60	Sg. Senggarang	Batu Pahat	Johor	1960	SG	36.87	3	10.42
37	5	129/40	Sg. Batu Pahat	Batu Pahat	Johor	1965	SG. CT	197.94	5	52.02
38	5	182/40	Sg. Muar	Muar	Johor	1968	SG. CT	385.34	11	51.88
39	23	063/40	Sg. Penarah	Segamat	Johor	1986	SG	36.13	1	30.76
40	23	065/90	Sg. Muar	Segamat	Johor	1970	SG	94.6	3	40
41	23	068/95	Sg. Bungor	Segamat	Johor	1960	CG	25.25	3	6.55
42	2	174/20	Sg. Dua	Bentong	Pahang	1974	SG	22.66	1	21.3
43	2	178/20	River	Bentong	Pahang	1974	SG	18.83	1	9.27
44	2	189/30	Sg. Menchir	Bentong	Pahang	1955	SG	31	3	11.94
45	2	232/20	Swamp	Temerloh	Pahang	1983	SG	283.5	15	18.65
46	2	235/00	Sg. Pahang	Temerloh	Pahang	1974	SG.SBX	231.45	17	17.63
47	2	258/5.0	River	Maran	Pahang	1955	SG	31.25	5	6.05
48	2	275/20	Sg. Kemak	Maran	Pahang	1956	SG	10.6	1	9.7
49	2	313/30	Sg. Leper	Kuantan	Pahang	1965	SG	73.2	6	12.2
50	2	356/70	Sg. Pahang	Kuantan	Pahang	1968	SG	247	12	30.33
51	2	New Br.	Sg. Pahang	Kuantan	Pahang	1993	SG	250-260	-	-
52	-	Bypass	Sg. Pahang	Kuantan	Pahang	1994	SG. BX	-	-	50
53	2	337/00	Sg. Balok	Kuantan	Pahang	1965	SG	65.59	7	9.02
54	2	337/50	Sg. Balok	Kuantan	Pahang	1965	SG	65.59	7	9.02

Table E.1 List of Inspected Bridges (2/2)

	FT Route No.	No	Crossing	District	State etc	Construct Year	Type of Super-str.	Total Length (m)	Span No.	Span Max (m)
55	3	385/80	Sg. Kemaman	Kemaman	Trengganu	1965	SG	267.65	16	28.03
56	3	392/10	Sg. Cukai	Kemaman	Trengganu	1963	SG	158.2	10	15.22
57	3	418/00	Sg. Kemasik	Kemaman	Trengganu	1955	SG	36.14	3	12.1
58	3	443/70	Sg. Paka	Dungun	Trengganu	1964	SG	356.06	23	12.18
59	3	460/60	Drainage Chan.	Dungun	Trengganu	1993	SG	42.2	1	30.64
60	3	522/90	Sg. Marang	Marang	Trengganu	1966	SG	142.68	6	23.78
61	3	532/80	Sg. Ibai	Trengganu	Trengganu	1957	SG	145.92	16	9.1
62	-	Bypass	Sg. Trengganu	Trengganu	Trengganu	-	SG	-	-	-
63	3	567/90	Sg. Lingai	Trengganu	Trengganu	1959	SG	55.22	9	5.9
64	3	587/90	River	Setiu	Trengganu	1965	SG	6.1	1	5.8
65	3	589/60	River	Setiu	Trengganu	1991	SG	23.9	1	18.6
66	3	611/10	Swamp	Setiu	Trengganu	1959	SG	36.92	4	9.09
67	3	642/10	Sg. Apai	Besut	Trengganu	1993	SG	30	1	24.7
68	3	650/30	Sg. Besut	Besut	Trengganu	1975	SG	305.18	5	30.52
69	3	658/90	River	Pasir Putih	Kelantan	1970	SG	36.5	2	17.83
70	3	666/60	Sg. Resau	Pasir Putih	Kelantan	1952	SG	33.66	6	5.41
71	3	670/40	River	Pasir Putih	Kelantan	1989	SG	55.3	3	16.46
72	3	690/40	Irrigation Canal	Pasir Putih	Kelantan	1972	SG	28.9	3	9.26
73	3	699/20	Sg. Pkln. Datu	Kota Bharu	Kelantan	1979	SG	127.26	5	31
74	134	Kelantan	Sg. Kelantan	Kota Bharu	Kelantan	-	BX	-	-	-
75	Constr.	Batu Kawa	Sg. Sarawak	Batu	Sarawak	1994	OT	292	8	38.5
76	Constr.	Btg. Kayan	Sg. Kayan	near Kuching	Sarawak	-	SG	112.3	5	30.5
77	-	Kanan	Sarawak Kanan	near Kuching	Sarawak	-	SG	85.3	3	30.5
78	-	Batu Kiga	Sg. Kiri Sawa	near Kuching	Sarawak	-	S-CG	94.5	3	48.5
79	-	-	Sg. Samarahan	near Kuching	Sarawak	-	OT	71	5	19.8
80	Constr.		Btg. Sadong	near Kuching	Sarawak	1994	S-CG, OT	112.3	9	44
81	-	-	Btg. Samarahan	near Kuching	Sarawak	1994	-	-	8	-
82	-	-	Sg. Empila	near Kuching	Sarawak	-	-	-	-	-
83	-	-	River	near Kuching	Sarawak	-	-	-	-	-
84	Constr.	Satok	Road (IC)	Kuching	Sarawak	1994	-	-	-	-
85	-	-	Sg. Sarawak	Kuching	Sarawak	-	SG	273.7	11	30.5
86	-	Santubong	Sg. Santubong	near Kuching	Sarawak	1988	BX, SG	593	13	146
87	-	Sibu	Sg. Sibu	Bintulu	Sarawak	-	SG	54.6	3	30.5
88	-	Kemena	Sg. Kemena	Bintulu-Miri	Sarawak	-	BX	457	11	53
89	-	4th Sibu	Sg. Sibu	Bintulu-Miri	Sarawak	-	OT	56	3	28
90	-	2nd Sibu	Sg. Sibu	Bintulu-Miri	Sarawak	1970	TR	61	3	48.8
91	-	Susi	Sg. Susi	Bintulu-Miri	Sarawak	-	TR	814	3	61
92	-	Sekeloh	Sg. Sekaloh	Bintulu-Miri	Sarawak	-	OT	56.1	3	18.9
93	-	Miri	Sg. Miri	Miri	Sarawak	-	SG	128	12	10.7
94	-	Tempanuli	Sg. Tuaran	Tampanuli	Sabah	(Assued) 198	S-AR	128.3	1	128.3
95		Gurun	Sg. Gurun-Gurun	Kota Belud	Sabah	1994	STG	12.2	1	12.2
96	-	Tempasuk	Sg. Tempasuk	near K. K.	Sabah	1962	BL	161.5	3	53.8
97	-	Tenghilan	Sg. Sulman	near K.K.	Sabah	-	-	-	-	-
98	-	Labuaya	Sg. Tuaran	Tuaran	Sabah	-	BL	112.1	3	
99	-	Darau	Sg. Darau	K. Kinabalu	Sabah	-	-	17	1	17
100	-	Yayasan	Sg. Likas	K. Kinabalu	Sabah	1974	CS	151.3	3	85.7
101	-	-	Sg. Inanam	K.Kinabalu	Sabah	1989	-	-	-	-
102	-	Dambai	Sg. Petagas	Dambai	Sabah	1964 (1965)	STG	50.1	3	25.7

Notes: 1) Types of superstructure are as follows:-

SG:	Simple girder	BX:	Concrete box girder
CG:	Continuous girder	SBX:	Steel box girder
CT:	Cantilever	TR:	Truss
AR:	Arch	STG:	Steel simple girder
FR:	Frame	BL:	Bailey Bridge
BC:	Box culvert	CS:	Cable stayed bridge
PC:	Pipe culvert	SAR:	Steel arch bridge
OT:	[illegible]		

Table E.2 BRIDGE INSPECTION SHEET

ROUTE :	BRIDGE NO:	NAME OF BRIDGE:	CROSSINGS :	DISTRICT:	STATE :	DATE OF INSPECTION :

PHOTOGRAPHS :

RESULTS OF INSPECTION & COMMENTS

SUPERSTRUCTURE :

* Main Beam : crack, honey comb, reinforcement bar exposed
  (Steel Bridge : deformation, rust, corrosion, falling off bolts)
* Diaphram : crack, honey comb, reinforcement bar exposed
  (Steel Bridge : deformation, rust, corrosion, falling off bolts)
* Deck Slab : crack, honey comb, reinforcement bar exposed
* End Diaphram : location, thickness, depth
* Int. Diaphram : location, thickness, depth
* Design Live Load : LTAL, MTAL, STAL, SSAL
* Others

BRIDGE ACCESSORIES :

* Bearing : function, wear, anc. bolt
* Expansion joint : function, damage, gap, abnormal noise
* Effect due to water leakage from drainage :
  Main beam, bearing seat, abutment, pier
* Pavement : pot hole, rutting
* Handrailing & Parapet
* Others

STRUCTURE DATA :

YEAR BUILT :
DESIGN LOADING :
CAPACITIES :
TYPE OF SUPERSTRUCTURE :
TYPE OF SUBSTRUCTURE :
ABUTMENT :
FOUNDATION :
PIER :
FOUNDATION :
TOTAL LENGTH :
SPAN LENGTH :
INTERNAL WIDTH BETWEEN PARAPETS :
CARRIAGEWAY WIDTH :
SKEW :
EXPANSION JOINT :
BEARINGS :
RESTRICTION OF WEIGHT :

SUBSTRUCTURE :

Abutment
* Crack, honey comb, reinforcement bar exposed
* Rotation, settlement, (abutment, behind, approach slab), sliding
* Embeded depth of pile cap/footing
* Scoring
* Structural adequancy

Pier
* Crack, honey comb, reinforcement bar exposed
* Rotation, settlement, slidding
* Embeded depth of pile cap/ footing
* Scoring
* Structural adequancy : pier section, pile cap section, pile exposed
* Others

HYDROLOGY :

* Crossing condition of the river
* Bridge Opening : width
  height
* Abutment : location
  embeded depth
* Pier : location, spanlength
  obstacle to flow
  embeded depth
  flouting woods
* River protection
* Remained old bridge at new bridge construction
* Others

4. Field Report of Bridge Specialist

4.1 First Survey in West Coast of Peninsular Northward in September 1 to 4, 1994.

4.1.1 Bridges Surveyed

Total 25 bridges were inspected in this trip along the federal road Route 1:18 in Perak, 2 in Penang and 5 in Kedah. Most wee the precast PC beams with the span length not over 30 m constructed in the 1970's and 80's. There were a few cast-insitu RC cantilever beams which were the constructions of the 1950's and 60's. Box culverts were used at several small water crossings which were the constructions of the 1960's and 70's. Comparatively new construction in the late 1980's and the early 90's was mostly the replacement of old RC beams by precast PC beams conforming to the JKR's recent standard design such as M-beam, I-beam and invert T-beam.

Most bridges had pile-bent type piers and abutments together with rubble pitching scour protection around abutments.

4.1.2 Findings

(1) Seriously damaged bridge was not found. Visible damages were limited to curb concrete, bridge rails and expansion joints.

(2) Most of elastomeric expansion joints were damaged where such joints were provided.

(3) Many of post tension PC I-beam bridges omitted providing chamfer when casting.

(4) Beam spacings of some PC I-beam bridges were found too conservative less than the standard 1.5 m.

(5) It was difficult for PC inverted T-beam bridges to recognize whether they were hollow or solid.

(6) Many elastomeric bearing pads were not sufficient in thickness compared with the JKR's standard design.

(7) Most abutments and piers of standard PC beam bridges were pile-bent type.

(8) Most of scour protections around pile-bent abutments were constructed with rubble pitchings and mesh rock-fill gabions. Some rubble pitchings were damaged because of insufficient embedding, no weepholes and no side stopper concrete provided.

(9) Past flood mark was found at one or two small bridges where soffit level was very low.

4.1.3 Others

Besides the above PC beam bridges, we found two custom-made, large, aged bridges being still visually in good conditions. One was the Perak River Bridge crossing the biggest river in the region by 6 spans of 60 m steel deck arches and the other was the Muda River Bridge called independent bridge consisting of RC cantilever beams at both side spans and 3 spans of 57 m RC through arches at center spans. Both were the constructions of the 1950's.

4.2 Second Survey in West Coast of Peninsula Southward in September 8 to 10, 1994

4.2.1 Bridges Surveyed

Total 16 bridges were inspected: 6 along the Route 1, 3 on the Route 3 and 9 on the Route 5, all in Johore. Many of old cast-insitu RC beam bridges supported by pile-bent piers and abutments with RC square piles, which were the constructions of the 1930's to the early 1960's were still in use at small to medium river crossings. Most of this type bridges were built up by cantilever structure to make spans longer. PC post-tension beam bridge was seen at several locations and which were the constructions from the late 1960's to the 80's to replace with old RC beam bridges. At relatively large river crossings such as Muar and Batu Pahat Rivers, where multispans of PC post-tension beams were supported by round pile-bent piers, the cantilever scheme was employed on the center span to secure an about 50 m long navigation way while the side spans were about 30 m each. Besides, three short span bridges of PC pretension beams constructed from the late 1960's to the early 70's, were observed, but it could not be distinguished whether the beams conformed to the JKR standard design or not.

4.2.2 Findings

(1) No serious structural damage was found on bridge structure itself. Visible damages were found on curbs, rails, expansion joints, and slope protections.

(2) Most of old construction bridges, many of which were RC cast-insitu beam type, were narrow of road width insufficient for dual two lane federal road standard.

(3) Pavement overlay became very thick in particular on old RC beam bridges, as much as 30 cm was observed.

(4) At some bridges near towns, the public utilities of water pipe mains were installed on sidewalks to hinder pedestrian.

(5) The bridges reconstructed by using the JKR standard PC beams in the 1980's were found much improved hydrologically compared to the previous ones such as (1) bridge formation level was raised, (2) abutments were set back and (3) longer beams were used to reduce the number of piers.

(6) For repair or replacement of expansion joints, rubberrized asphalt mix filler was used on several bridges and which seemed to achieve a certain success for smooth vehicle running.

(7) At many bearing shoes, anchor bolts or retainers were not provided and that was probably because of rare earthquake occurrence.

(8) At large river crossings bridged by multi-span PC beams, the center span was in many cases built by cantilever structure in combination with standard PC beams in order to achieve wider navigation way. However, this cantilever scheme was not structurally stable because the support distance of cantilever beams were too short and as a result of that vibration of the cantilever span when heavy vehicles passing has been a problem since the construction.

(9) Many pile caps of piers were embedded shallow or not embedded, and where many piles were found exposed by scouring.

(10) On the bridges along the Route 5, salt damage was observed little although they are very close to sea. Only at the Pontian Besca river bridge, anti-corrosion paint was being applied on the underside of PC beams and the pier columns above water.

4.2.3 Construction Site

Along the Route 5 we saw three ongoing bridge construction sites; two were the scene of piling work for the replacement of small river bridge and the other was a site casting of PC post-tension beams near the completed abutments of a railway overbridge.

At the piling work, the detour way had been already prepared by bailey girders adjacent to the construction, and RC spun piles of diameter about 40 cm were being driven by a diesel hammer utilizing the existing bridge deck as a driving stage.

At the PC beam casting site, we could see the various stages of PC post-tension beam casting works such as re-bars and PC cables arrangement, form installation and immediate after concrete placing but tensioning had not yet done. Following points were noted.

(1) Although side from was made with steel, form support was not rigid enough because of no separate tie used.

(2) Re-bars were round bars but deformed bars were not used.

(3) The dead anchors of PC cables were made by bending PC cables but no anchor plates and blocks were used. This method was economical but might bring about local tensile stresses in the narrow beam end by stressing PC cables.

(4) Casting base was not firmly prepared in particular at both the beam ends where sufficient bearing support is required when and after stressing.

4.3 Third Survey in East Coast of Peninsula in North Half and Sarawak/Sabah in September 14 to 25, 1994

4.3.1 Bridges Surveyed

Total 60 bridges were inspected: 7 along the inland Route 2 for Kuala Lumpur to Kuantan, 25 along the east coastal Route 3 from Kuantan to Kota Bahru, 19 in Sarawak around Kuching and on the route from Bintulu to Miri and 9 in Sabah around Kota Kinabalu. At the small to medium bridges on the east coast of Peninsular, replacement construction of old RC bridges with wider and longer structures was being undertaken by applying the JKR's standard PC beams. In Sarawak and Sabah, the application of standard PC beams was not common. In particular in Sabah, steel bridge was more popular than concrete bridge.

4.3.2 Findings

4.3.2.1 Kuala Lumpur to Kuantan Mountainous Area

(1) Short to medium span bridges reconstructed by PC post-tension beams in the 1970's to 80's were found considerably improved both in traffic service and in river hydrology compared to previous bridges as follows:

(i) Road width was widened, in particular enough shoulder width and sidewalk were provided.

(ii) Abutment position was set back and longer beams were adopted to reduce number of piers.

(iii) Road formation and beam soffit level were raised to secure more vertical clearance.

(iv) Rubble pitching slope protection and mesh rock-fill gabion were used around abutments.

However, in some location old abutment concrete remained in river and which should hinder flood flow.

(2) RC cast-in-situ bridges, many of which were built in the 1950's, were still in use although they were weathered and worn out for years, but bridge width and loading capacity became insufficient for increase of traffic. Replacement of such short to medium span bridges will be a urgent work for JKR in next five years according to the state JKR staff.

(3) Damages, although which were not structurally serious, were observed often around pile-bent abutments rather than superstructures and piers. Many wing walls and rubble protections at abutments were broken.

(4) Mesh rock-fill gabion and rubble pitching were widely used for river bank protection against scouring, but problem was the shallow embedment which allow scour the foot of protection.

4.3.2.2 Kuantan to Kota Bahru Coastal Area

(1) Salt damage was often seen on abutments and piers rather than superstructures. Columns and piles near on tidal level were severely damaged by salt water: concrete surface was crumbled and reinforcements were exposed and much corroded. The concrete bridges built in the 1960's by pile-bent structure were in progress of repair work for salt damage by JKR. Besides, at the Kuantan river bridge which was under construction with PC cantilever box girder for center spans and PC post-tension beams for side spans, protective coating paint was being applied both on super- and sub-structures.

(2) Most of piers surveyed were built by pile-bent structure even of the important bridges crossing the big rivers like Kuantan, Trengganu and Kelantan. Because, the construction method of this structure of driving piles and then casting a pile cap above water level is much easier than embedding a footing on river bottom which must involve costly and difficult cofferdam work especially in deep water. However, the design of pile bent piers needs careful attention to the changes of river bottom by scouring which undermines the stability of piers.

(3) Many expansion joints were more or less damaged where pre-fabricated expansion joints were placed. In particular, damages were often seen on rubber joints and which seemed to have begun from inadequate installation work and worsened by constant traffic impact. For replacement of damaged joints and also in new construction, the use of rubberized asphalt mix filler was seen at many PC beam bridges and which seemed to be a certain success in achieving smooth road surface.

(4) To eliminate troublesome expansion joints, beam coupling treatment was seen in several multi-span PC beam bridges, that is the joint gaps between neighboring beams on piers were integrated in bridge direction by filling concrete and deck slab was constructed continuously without expansion joints after simple PC beams were erected individually. This beam coupling scheme

is easy to be adopted in this country because of small temperature change and few earthquake occurrence.

(5) Some bridges did not have a cross beam at the middle of span but certain bridges had. Although the main function of cross beam is to distribute loads among longitudinal beams, it was hard to understand why cross-beams were designed or not designed. There were many examples both of with and without cross-beams.

4.3.2.3 Around Kuching and Bintulu to Miri in Sarawak

(1) In Sarawak, so far, steel bridges have been built more than concrete bridges and the application of the standard design of JKR has not been so enthusiastic, because the scale of the rivers in the state is generally larger, bridge construction has not been so many in the limited road network and therefore the access to bridge site was not easy compared to in the Peninsular states.

(2) Several examples of steel girder bridges of continuous structure and composited with RC deck slab, were seen at medium size of river crossings, where together with a continuous steel girder supported by pile-bent piers, single or two to three spans of RC beams were used for approach spans at either bank. However, watching the details of steel structures, they were designed and constructed in many different ways such as:

(i) Of transverse bracings, against the general use of shape steel frame or rolled I-beam, a rolled steel I-beam bridge had concrete cross-beams connected to main beams by bolts.

(ii) Of main girders, both of rolled steel I-beam and welded steel plate girder were seen and high tension bolts were generally used for field splice jointing, but a rolled steel I-beam bridge was found assembled entirely by field welding.

(iii) Of bearing shoes, comparatively old steel bridges had steel rocker bearings but recent construction was provided with rubber pads.

However, a few of PC post-tension beam bridges were seen at medium size of river crossing along the rural roads near Kuching. One of these PC bridges, the Samarahan river bridge completed this year adopted the beam connecting scheme to eliminate expansion joints.

(4) At the construction site of an interchange in Kuching, PC pretension beams were being used and that was, according to the state JKR staff, a very rare case to produce PC pretension beams at the only factory "Home" in the city, because the market of PC pretension beams was very small in Sarawak. On the cut ends of the beams, PC cables were exposed and rusted for no

treatment was provide.

(5) At the same interchange construction site, small triangle RC pile were being constructed under the approach road because the earth banking was rather high and the ground was soft to predict settlement.

(6) At long river crossings and where large navigation clearance is required, bridge was constructed based on the individual design with the consideration of local conditions. The examples of that were the Santubong bridge constructed by PC cantilever box girder in 1988 to cross the Sarawak river near to sea at the north of Kuching and the other was the Kemena river bridge of multi-span continuous PC segmental box girder seen on the way from Bintulu to Miri.

(7) On the way from Bintulu to Miri, two steel truss bridges constructed in the 1970's under the Australian Colombo plan were seen. These bridges were assembled at the site with standard steel truss members and on either approach span rolled steel I-beams were adopted.

4.3.2.4 Around Kota Kinabalu and Kota Kinabalu to Sandakan in Sabah

(1) In Sabah, most bridges have been built by steel and actually concrete bridge was not seen except a few old small cast-in-situ RC beams and a recent completion of the Inaam river bridge of cast-in-situ PC box girder at the suburb of Kota Kinabalu. Most common type of steel bridge on small to medium size of rivers was the combination of rolled steel I-beam and RC deck slab.

(2) Concrete aggregate is collected enough in quantity from river gravel, but in quality it is not hard enough to use for high strength concrete like prestressed concrete because the river gravel is made of sand stone. That is the most reason for PC bridges not to have been built in Sabah. Recently a precast concrete factory was set up in Kota Kinabalu but it has not yet started the PC beam production because of no market demand.

(3) In Sabah, bridge construction has been carried out based on individual design and mostly by the hands of local contractors. Because of the technical difficulties and complications of the site of building PC bridges, the state JKR has rather preferred to import the pre-fabricated steel plate girders for easier site work and handling. In addition, there was a very limited heavy construction equipment in Kota Kinabalu.

(4) The Tamparuli river bridge, located about 40 km east of Kota Kinabalu, one of the largest bridges in Sabah, was constructed in 1979 with a 110 m long steel langer arch. It was surprised that the steel arch had been fabricated, welded and assembled of its all members at the site and launched by winch on the temporary stagings for erection with many difficulties, according to the

state JKR staff. The bridge now suffered troubles on the bearing shoes which were crushed and on the abutments where many moment cracks occurred. Compared to the size of superstructure, the bearings and the abutments seemed to be too small.

(5) In Sabah, there were some bailey bridges constructed in the 1960's as temporary bridges with timber deck. Even now, these bailey bridges are in service with danger and inconvenience: the bridges have to be passed alternately for the narrow width and to restrict the maximum vehicle weight at 15 t. However, actually heavy lorries with full load of timbers and aggregate were passing and a span of bailey bridge had collapsed early this year. Replacement of such temporary bridges to permanent bridges is the most urgent problem for the state JKR.

5. Field Report of Hydrology Specialist

Hydrological conditions at 73 bridge sites in Peninsular Malaysia and at 28 bridge sites in Sabah and Sarawak were surveyed and reported as follows.

5.1 River Course at Bridge Site

(1) In the northwestern area of Peninsular Malaysia such as in Kedah and Perak, there were many bridges crossing rivers at curved or meandering reach and among them not a few bridges crossed skew to river courses.

(2) While in the southern and eastern areas such as Johor, Pahang and Terengganu, bridges crossed rivers more in straight reach and normal angle to river courses.

(3) In Sabah and Sarawak, the number of bridges which cross in curved reach is rather big. This is due to the characteristics of river configuration with severe meandering in these areas. But the number of the bridges with skewed crossing direction is rather small in Sarawak. Some cases could be seen in Sarawak that the alignment of the road was seemed to be arranged so as to cross the river with normal crossing direction.

COMMENTS

(1) It is desirable to cross the rivers or drainage channels in the straight river reach with normal crossing direction.

(2) But sometimes it become necessary to cross the rivers in curved channel or with skewed crossing direction. In this case, bridge site should avoid as much as possible the big curved reaches as well as the skewed angle should be as small as possible. Furthermore, it is necessary to provide adequate protection for the river banks around the bridge to prevent erosion of river banks as well as the foundation of abutments which will be caused by the turbulence of current. On the contrary, bank protection are not enough for the bridges which cross curved channel or with skewed angle in Peninsular Malaysia as well as in Sabah and Sarawak.

5.2 Bridge Opening

The condition of bridge opening for the inspected bridges are as follows:

(1) Only 15 bridges out of 101 inspected bridges in Peninsular Malaysia and Sabah and Sarawak have enough width and height of bridge opening. Even among the inspected bridges crossing the major rivers, the bridges of the Muda, Muar, Batu Pahat, Pahang, Kuantan and Kelantan rivers in Peninsular Malaysia as well as the Labuk, Tuaran and the Sarawak rivers in Sabah and Sarawak have problems relating to the bridge opening.

(2) It could be observed at many bridge sites that the abutments were located inside of the river channel.

In this case, the width of bridge opening become smaller than the width of flood flow. Then, constriction flow pattern will be formed at the bridge site. In the subcritical flow condition, which is the general flow condition of the rivers in Malaysia, the profile of water surface become gentle in just upstream of the bridge due to the backwater effect caused by the constriction, and then go down very rapidly at the bridge and gradually go up in just downstream of the bridge.

Hence, the constriction flow sometimes make the flood water level higher in the upstream each of the bridge. Furthermore, due to the local strong current with big turbulence made by the rapidly varied flow of the constriction flow, erosion of the river banks and foundation of abutments as well as local scouring around piers are easily to be occurred.

Among the many inspected bridges which have small bridge opening width, erosion problem of river banks as well as foundation of abutments could be observed.

(3) Many inspected bridges have not enough height between the river bed and the bottom of the beam. In other words, the freeboard between the flood water level and the bottom of the beam seems to be small in many bridges.

In many cases, flood marks could be seen on the beam of bridges or there are information that the flood water have reached up to the beam. It means that the freeboard between the flood water level and the bottom of the beam is not sufficient and the safety of the bridge stability is reduced.

Furthermore, if the flood water reaches to the beam, flood flow will be dammed up. By this, the flood water level in the upstream each of the bridge will be made higher and it will make worse the flood damage in the upstream reach. Furthermore, there are many reports in the world including Japan that the bridge itself were flushed away and caused tremendous flood damage to the downstream reaches.

COMMENTS

(1) It is necessary to keep the width of bridge opening wider than the width of design flood. In other words, the locations of the abutments should be outside of the design river width so as not to make constriction flow pattern around the bridge.

(2) The height of the bridge opening is necessary to contain enough freeboard between the design high water level and the bottom of the beam.

5.3 Pier Condition

Condition of the piers is as follows;

(1) About 60 % of inspected bridges in Peninsular Malaysia and about 50 % of inspected bridges in Sabah and Sarawak have small span length of piers.

If the span length is small, floating logs will be easily to be captured by the piers and they will affect the safety of the bridge.

(2) Many pile bent piers with square or round piles could be seen in the inspected bridges in Peninsular Malaysia as well as in Sabah and Sarawak. Furthermore, there are also many cases that the piers have oval shaped wall with exposed multiple piles with pile cap in the water. Sometimes, big protection wall against floating logs or ships are provided around the pile cap.

These types of piers not only disturb the flood flow but also make problems of local scouring around the piers as well as bank erosion due to the big turbulence caused by the piers.

(3) Several bridges have the piers with skewed alignment against the flow

Especially, if the piers are pile bent, the skewed alignment will make worse the flow pattern around the bridge and floating logs become more easily to be captured. There are several bridges in Peninsular Malaysia as well as in Sabah and Sarawak which capture many floating logs by the piers.

<u>COMMENTS</u>

(1) There is a criteria for minimum span length of piers in Japan relating to the design flood discharge. For example, the minimum span length should be more than 20 m for the bridges crossing the middle size of rivers with design flood discharge between 500 to 2000 m3/s. Many rivers with middle size could be seen during the investigation. This criteria was made referring to the many experiences of damages to the bridges in Japan caused by the floating logs. But these experiences seem to have universal applicability.

(2) The shape of piers should be oval shaped as much as possible. But, if the flow direction in the rivers around the bridge is changing very much, round shape column can be applicable. But even in this case, multiple column should be avoided. The pile caps are necessary to be installed below the design river bed with sufficient depth considering the local scouring around the piers and height of sand bars.

(3) The alignment of the piers should be parallel to flow direction so as to avoid making worse the disturbance around the piers and to flow down the floating logs smoothly.

5.4 Abutment Condition

(1) There are many inspected bridges which have their abutments inside of the river channel as mentioned in the bridge opening width.

(2) In many cases, the type of the abutments are pile bent or RC bank seat with pile foundation both in Peninsular Malaysia and Sabah and Sarawak.

Erosion problem around the foundation of these abutments could be seen for these bridges even though the protection for foundation of abutments are provided by rubble concrete or gabion mat etc.

(3) In several cases, the direction of the surface of the abutments are not parallel to flow especially in the skewed bridges.

This will disturb the flood flow as well as cause severe erosion around the abutments.

<u>COMMENTS</u>

(1) The locations of the abutments should be outside of the design river channel as mentioned in the bridge opening.

(2) Hence, the pile bent or bank seat type of abutment has very shallow foundation depth, type of abutments should be RC wall including gravity and inverted T wall. The bottom of the abutment should be below the original ground.

(3) The surfaces of the abutment should have parallel direction to flow.

5.5 River Bank Protection around Bridge

(1) In many cases, bank protections are only provided around abutments or not provided. Therefore, river bank protection around the bridges were not sufficient.

Problem of bank erosion could be seen around the bridge in many cases especially in Sabah and Sarawak.

(2) As the foundation depth of bank protection is small, there are many bridges with damaged bank protection due to the erosion of its foundation.

<u>COMMENTS</u>

(1) River bank protections are necessary to be provided not only around the abutments but also around the bridge site with adequate total length such as 10 m for the upstream and 10 m for the downstream.

(2) The foundation of the abutment is necessary to be installed below the design river bed with sufficient depth considering the local scouring by the sand bars etc. If the problem of local scouring will be anticipated very much, foot protection for the bank protection is also necessary to be provided by using stones with enough weight etc.

5.6 *Other Conditions*

(1) Floating logs

There are some bridges in the western area and eastern area of Peninsular Malaysia which have many floating logs. Some bridges of Sabah have many floating logs.

The piers of some bridges are damaged by floating logs in Peninsular Malaysia as well as in Sabah.

(2) Remaining old bridge near the bridge site

There are some bridge which have un-demolished old bridges near the bridge site. The old bridges disturb the flood flow.

(3) *Sediment discharge in the river*

Due to the urgent industrialization and changing plantation from rubber tree to oil palm tree, cutting woods and development of land can be seen in wide area in Peninsular Malaysia. This has an effect of increasing sediment discharge of the river. Sediment deposition could be seen in some bridges especially in the western area of Peninsular Malaysia during the investigation.

If the sediment deposition happen, flow capacity of the bridge section will be decreased and the flood water level in ad around the bridge site will be made higher.

(4) Mining of river sand

There was one bridge in Sabah which has been made damage to its pier by mining of sand. Excessive mining of river sand sometimes make degradation of the river bed. In general, the foundation of the abutments, piers and bank protection are damaged by the degradation.

<u>COMMENTS</u>

(1) In order to pass the floating logs smoothly through the bridge, piers should be provided with enough span length as well as with oval shaped and parallel direction to flow. Furthermore, the pile cap of the pier should be under the

river bed. The abutment should be outside of the river channel with parallel direction of their surface to the flow. River bed protection also should be properly provided if the many floating logs is anticipated.

(2) Old bridge should be demolished completely

(3) If sediment deposition happen in and around the bridge, proper dredging with periodical interval should be provided for maintenance of the river cross section in and around the bridge.

(4) Excessive mining of river sand should be prohibited.

Table E.3 Summary of Hydrological Condition of the Inspected Bridges in Peninsular Malaysia (1/7)

FT No.	Bridge No.	State	Const. Year	Total Length (m)	Span No.	Span Max. (m)	Crossing Condition: River Course	Crossing Condition: Crossing	Bridge Opening: Width	Bridge Opening: Height	Pier: Type	Pier: Span Length	Pier: Direction to Flow	Pier: Foundation Depth	Abutment: Type	Abutment: Foundation Depth	River Bank Protection around Bri.
1	481/70	Perak	1969	49.20	4	12.30	curve	skewed	small	-	square-pile bent	small	parallel	-	RC bank seat	-	around abut. only
1	498/20	Perak	1963	37.27	3	12.32	curve	skewed	small	small	square-pile bent	small	skew	-	pile bent	-	around abut. only
1	509/80	Perak	1941	7.00	1	6.53	straight	skewed	small	-	-	-	-	-	pile bent	-	around abut. only
1	522/80	Perak	1990	30.00	1	24.30	curve	skewed	small	small	-	-	-	-	invisible	-	no
1	528/70	Perak	1970	32.24	1	30.70	straight	normal	small	small	-	-	-	-	RC wall	-	no
1	539/50	Perak	1991	63.20	3	24.40	straight	normal	small	small	oval shaped wall	enough	parallel	-	invisible	-	enough
1	548/80	Perak	1974	25.24	1	18.70	curve	skewed	small	small	-	-	-	-	RC bank seat with pile found.	small	around abut. but weak
1	564/50	Perak	1972	41.13	3	13.71	curve	skewed	small	small	square-pile bent	small	parallel	-	pile bent	-	around abut. only
1	580/90	Perak	1967	18.37	3	8.00	curve	normal	small	small	square-pile bent	small	parallel	-	bank seat	-	no
1	589/80	Perak	1960	5.50	3	1.83	straight	normal	small	small	-	-	-	-	invisible	-	no
1	662/10	Perak	-	-	1	-	curve	normal	small	small	-	-	-	-	invisible	-	enough
1	662/40	Perak	-	-	1	-	curve	normal	small	small	-	-	-	-	invisible	-	enough
1	677/10	Perak	1992	36.40	1	30.80	curve	skewed	small	-	-	-	-	-	invisible	-	provided but short
1	686/80	Perak	1950	106.40	5	21.00	straight	normal	small	small	oval shaped solid wall caison	enough	parallel	-	pile bent	-	around abut. only
1	696/90	Perak	1985	118.00	3	43.30	straight	normal	small	small	RC wall with cantilever	enough	parallel	-	RC bank seat with pile found.	-	no
1	750/80	Purau Pinang	1969	59.44	6	11.25	-	-	-	-	-	-	-	-	-	-	-
1	757/00	Purau Pinang	1965	218.03	7	31.29	straight	normal	enough	enough	round-pile bent with wall	enough	parallel	-	pile bent	-	no

Table E.3 Summary of Hydrological Condition of the Inspected Bridges in Peninsular Malaysia (2/7)

FT. No.	Bridge No.	State	Const. Year	Total Length (m)	Span No.	Span Max. (m)	CONDITION OF BRIDGE: Crossing Condition: River Course	Crossing	Bridge Opening: Width	Height	Pier: Type	Span Length	Direction to Flow	Foundation Depth	Abutment: Type	Foundation Depth	River Bank Protection around Bri.
1	782/10	Purau Pinang	1954	273.14	3	57.32	straight	normal	enough	enough	oval shaped wall	enough	parallel	-	free cantilever beam	-	no
1	783/80	Kedah	1925	14.70	2	7.35	-	-	-	-	-	-	-	-	-	-	-
1	803/30	Kedah	1992	36.50	1	30.80	curve	skewed	small	small	-	-	-	-	invisible	-	around abut. only
1	807/00	Kedah	1957	38.00	5	12.20	curve	skewed	small	-	oval shaped wall	small	parallel	-	free cantilever beam	-	no
1	814/50	Kedah	1977	32.20	1	30.30	-	-	-	-	-	-	-	-	-	-	-
1	820/40	Kedah	1970	14.60	1	11.80	curve	normal	small	-	-	-	-	-	bank seat	-	no
6	014/10	Purau Pinang	1985	79.35	5	18.25	straight	normal	enough	small	oval shaped RC stem	enough	parallel	-	bank seat	-	no
6	017/50	Purau Pinang	1985	429.44	17	30.74	-	-	-	-	-	-	-	-	-	-	-
1	072/90	Johor	1930	12.20	1	12.20	straight	normal	small	-	-	-	-	-	pile bent with wall	-	around abut. only
1	081/0.5	Johor	1954	27.40	3	15.90	straight	skewed	small	small	oval shaped RC wall with pile found.	small	parallel	small	RC wall with pile found.	-	no
1	185/40	Johor	1960	76.87	3	33.53	straight	normal	small	small	oval shaped RC wall	enough	parallel	-	RC wall with pile found.	-	around abut. only
1	197/80	Johor	1970	45.72	3	15.24	straight	normal	small	small	oval shaped RC wall with pile found.	small	parallel	-	RC wall with pile found.	-	no
1	202/50	Johor	1982	38.43	3	18.25	straight	normal	small	-	oval shaped RC wall	enough	parallel	enough	RC bank seat	-	enough
1	226/10	Melaka	1964	35.52	3	12.35	curve	skewed	small	small	square-pile bent	small	parallel	-	RC bank seat with pile found.	-	around abut. but damaged
5	025/20	Johor	1940	20.47	3	12.21	straight	normal	enough	enough	RC column	enough	parallel	enough	invisible	-	enough

Table E.3 Summary of Hydrological Condition of the Inspected Bridges in Peninsular Malaysia (3/7)

FT No.	Bridge No.	State	Const. Year	Total Length (m)	Span No.	Span Max. (m)	Crossing Condition: River Course	Crossing Condition: Crossing	Bridge Opening: Width	Bridge Opening: Height	Pier: Type	Pier: Span Length	Pier: Direction to Flow	Pier: Foundation Depth	Abutment: Type	Abutment: Foundation Depth	River Bank Protection around Bri.
5	056/90	Johor	1966	72.54	6	12.20	curve	normal	small	enough	round-pile bent	small	parallel	-	pile bent	-	no
5	085/50	Johor	1970	50.76	3	18.28	straight	skewed	small	small	square-pile bent	small	parallel	-	RC bank seat with pile found.	-	no
5	092/10	Johor	1960	21.70	5	2.70	straight	skewed	small	small	-	-	-	-	-	-	not enough
5	105/60	Johor	1960	36.87	3	10.67	curve	normal	small	small	square-pile bent	small	parallel	-	pile bent	-	no
5	129/40	Johor	1965	197.94	5	52.02	straight	normal	enough	enough	2 lined round-pile bent	enough	parallel	-	bank seat with pile found.	-	no
5	182/40	Johor	1968	385.34	11	51.88	straight	normal	enough	small	1 and 2 lined PC pile bent	enough	parallel	-	pile bent wth PC pile	-	enough
23	063/40	Johor	1986	36.13	1	31.40	straight	skewed	small	-	-	-	-	-	invert-T	-	no
23	065/90	Johor	1970	94.60	3	40.00	straight	skewed	small	small	RC wall with pile found.	enough	parallel	enough	bank seat with pile found.	small	no
23	068/95	Johor	1960	25.25	3	6.85	straight	normal	small	small	square-pile bent	small	parallel	-	RC wall with pile found.	-	no
2	174/20	Pahang	1974	22.66	1	21.30	straight	normal	small	small	-	-	-	-	RC wall	-	enough around abut. only
2	178/20	Pahang	1974	18.83	1	9.73	curve	normal	small	small	-	-	-	-	RC wall	-	
2	189/30	Pahang	1955	31.00	3	12.20	curve	skewed	small	-	square-pile bent	small	skewed	-	pile bent	-	around abut. only
2	232/20	Pahang	1983	283.50	15	18.90	-	normal	enough	enough	oval shaped RC wall	enough	-	enough	bank seat	-	-
2	235/00	Pahang	1974	231.45	17	17.63	straight	normal	enough	enough	oval shaped wall with V shaped column	enough	parallel	-	bank seat with pile bent	-	not enough

Table E.3 Summary of Hydrological Condition of the Inspected Bridges in Peninsular Malaysia (4/7)

FT No.	Bridge No.	State	Const. Year	Total Length (m)	Span No.	Span Max. (m)	CONDITION OF BRIDGE: Crossing Condition: River Course	Crossing	Bridge Opening: Width	Height	Pier: Type	Span Length	Direction to Flow	Foundation Depth	Abutment: Type	Foundation Depth	River Bank Protection around Bri.
2	258/5.0	Pahang	1955	31.25	5	6.25	curve	normal	small	small	square-pile bent	small	parallel	-	bank seat with pile found.	-	no
2	279/20	Pahang	1956	10.60	1	9.40	straight	skewed	small	small	-	-	-	-	RC wall with pile found.	enough	no
2	313/30	Pahang	1965	73.20	6	12.20	straight	skewed	small	small	square-pile bent with oval shaped RC wall with square pile found.	small	parallel	-	RC wall with pile found.	-	around abut. only
2	356/70	Pahang	1963	247.00	12	31.25	curve	normal	small	small	oval shaped RC wall with pile found. and square pile cap	enough	skewed to flow but parallel to river bank	-	counterfort wall with pile found.	-	no
2	New Br.	Pahang	1993	250-260	-	-	curve	normal	enough	enough	inverted T wall with pile found.	enough	skewed to flow but parallel to river bank	-	inverted T with pile found.	-	no
-	Bypass	Pahang	1994	-	-	-	straight	normal	enough	enough	multiple column solid wall piled with skirting wall	enough	parallel	-	invert-T	-	not enough
2	377/00	Pahang	1965	65.59	7	9.37	straight	normal	small	small	round-pile bent	small	parallel	-	bank seat with pile found.	-	not enough

Table E.3 Summary of Hydrological Condition of the Inspected Bridges in Peninsular Malaysia (5/7)

FT No.	Bridge No.	State	Const. Year	Total Length (m)	Span No.	Span Max. (m)	CONDITION OF BRIDGE: Crossing Condition: River Course	Crossing	Bridge Opening: Width	Height	Pier: Type	Span Length	Direction to Flow	Foundation Depth	Abutment: Type	Foundation Depth	River Bank Protection around Bri.
3	385/80	Terengganu	1965	267.65	16	28.03	curve	normal	enough	enough	multiple round column with square pile cap	small	parallel	-	pile bent	-	no
3	392/10	Terengganu	1963	158.20	10	15.22	curve	normal	small	small	RC cylinder piles of 4 nos.	small	parallel	-	rigid frame with RC cylinder piles of 4 nos.	-	around abut. only
3	418/00	Terengganu	1955	36.14	3	12.10	straight	normal	small	small	square-pile bent	small	parallel	-	pile bent	-	around abut. only
3	443/70	Terengganu	1964	356.06	23	15.22	straight	normal	small	small	RC cylinder piles of 4 nos.	small	parallel	-	rigid frame with RC cylinder piles of 4 nos.	-	no
3	460/60	Terengganu	1993	42.20	1	30.64	curve	normal	-	small	-	-	-	-	invisible	-	enough
3	522/90	Terengganu	1966	142.68	6	23.78	straight	normal	small	-	round-pile bent	enough	parallel	-	retaining wall with pile found.	-	around abut. only
3	532/80	Terengganu	1957	145.92	16	9.10	straight	normal	small	small	square-pile bent	small	parallel	-	bank seat	-	not enough
-	Bypass	Terengganu	-	-	-	-	straight	normal	enough	enough	solid wall inverted T pier with pile cap	enough	parallel	-	bank seat	-	around abut. only
3	567/90	Terengganu	1959	55.22	9	6.14	curve	normal	small	enough	square-pile bent	small	parallel	-	pile bent	-	no

Table E.3 Summary of Hydrological Condition of the Inspected Bridges in Peninsular Malaysia (6/7)

FT No.	Bridge No.	State	Const. Year	Total Length (m)	Span No.	Span Max. (m)	CONDITION OF BRIDGE: Crossing Condition: River Course	Crossing Condition: Crossing	Bridge Opening: Width	Bridge Opening: Height	Pier: Type	Pier: Span Length	Pier: Direction to Flow	Pier: Foundation Depth	Abutment: Type	Abutment: Foundation Depth	River Bank Protection around Bri.
3	587/90	Terengganu	1965	6.10	1	6.04	curve	normal	small	small	-	-	-	-	square-pile bent	-	around abut. only but damaged
3	589/60	Terengganu	1991	23.90	1	18.60	straight	normal	small	small	-	-	-	-	bank seat	-	no
3	611/10	Terengganu	1959	36.92	4	9.23	swamp	normal	enough	-	square-pile bent	enough	-	-	pile bent	-	around abut. only
3	642/10	Terengganu	1993	30.00	1	24.70	curve	normal	small	enough	-	-	-	-	bank seat	-	around abut. only
3	650/30	Terengganu	1975	305.18	5	31.38	curve	normal	enough	small	oval shaped solid wall with exposed round pile found.	enough	parallel	-	bank seat with pile found.	-	not enough
3	658/90	Kelantan	1970	36.50	2	18.25	straight	skewed	enough	enough	oval shaped solid wall with pile found	enough	parallel	-	bank seat with pile found.	-	around abut. only
3	666/60	Kelantan	1952	33.66	6	5.61	curve	skewed	small	small	square-pile bent	small	skewed	-	pile bent with RC pile found.	-	around abut. only but damaged
3	670/40	Kelantan	1989	55.30	3	16.76	curve	normal	enough	enough	oval shaped solid wall with pile found	enough	parallel	enough	bank seat with pile found.	-	no
3	690/40	Kelantan	1972	28.90	3	9.50	straight	normal	small	small	2 lined square-pile bent	small	parallel	-	bank seat with pile found.	-	no

Table E.3 Summary of Hydrological Condition of the Inspected Bridges in Peninsular Malaysia (7/7)

FT No.	Bridge No.	State	Const. Year	Total Length (m)	Span No.	Span Max. (m)	CONDITION OF BRIDGE: Crossing Condition: River Course	Crossing	Bridge Opening: Width	Height	Pier: Type	Span Length	Direction to Flow	Foundation Depth	Abutment: Type	Foundation Depth	River Bank Protection around Bri.
3	699/20	Kelantan	1979	127.26	5	31.24	straight	normal	small	enough	2 lined exposed round pile found. with square pile cap and oval shaped solid	small	parallel	-	bank seat with pile found.	-	no
134		Kelantan	-	-	-	-	curve	normal	small	small	multiple column with pile cap and exposed pile found.	small	parallel	-	bank seat with pile found.	-	not enough

Table E.4 Summary of Hydrological Condition of the Inspected Bridges in Sabah and Sarawaku (1/3)

FT No.	Bridge No.	State	Const. Year	Total Length (m)	Span No.	Span Max. (m)	CONDITION OF BRIDGE: Crossing Condition: River Course	Crossing	Bridge Opening: Width	Height	Pier: Type	Span Length	Direction to Flow	Foundation Depth	Abutment: Type	Foundation Depth	River Bank Protection around Bri.
-	1	Sarawak	1994	292.00	10	38.50	curve	normal	enough	enough	oval shaped inverted T with exposed pile found. with pile cap	enough	parallel	-	bank seat, rigid frame (portal) with pile found.	-	around abut. only
-	2	Sarawak	-	-	3	-	curve	normal	small	small	rectangular multiple column with pile found. and square pile cap on the bed	small	parallel	-	buttressed with pile found.	-	around abut. only but damaged
-	3	Sarawak	-	-	-	-	curve	normal	small	enough	rectangular multiple column with pile foundation and pile cap	enough	parallel	-	rigid frame with pile found.	-	no
-	4	Sarawak	-	-	3	-	straight	normal	small	enough	multiple column with pile found.	enough	parallel	-	rigid frame with pile found.	-	no
-	5	Sarawak	-	-	-	-	straight	normal	small	small	multiple square pile bent	small	parallel	-	rigid frame with pile found.	-	no
-	6	Sarawak	1994	250.00	9	44.00	curve	normal	enough	enough	oval shaped inverted T wall with pile found.	enough	parallel	-	inverted T with pile found.	-	no
-	7	Sarawak	1994	-	8	-	straight	normal	enough	small	oval shaped inverted T wall with exposed pile found. and big skirting wall	enough	parallel	-	bank seat with pile found.	-	no
-	8	Sarawak	-	-	-	-	straight	normal	small	small	oval shaped inverted T wall with pile found.	enough	parallel	-	bank seat with pile found.	-	no
-	9	Sarawak	-	-	-	-	straight	normal	small	small	oval shaped inverted T wall with pile found.	enough	parallel	-	bank seat with pile found.	-	no
-	10	Sarawak	1994	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	11	Sarawak	-	-	-	-	straight	normal	enough	enough	oval shaped inverted T with pile found.	small	parallel	-	bank seat with pile found.	-	not enough

Table E.4 Summary of Hydrological Condition of the Inspected Bridges in Sabah and Sarawaku (2/3)

FT No.	Bridge No.	State	Const. Year	Total Length (m)	Span No.	Span Max. (m)	Crossing Condition: River Course	Crossing Condition: Crossing	Bridge Opening: Width	Bridge Opening: Height	Pier: Type	Pier: Span Length	Pier: Direction to Flow	Pier: Foundation Depth	Abutment: Type	Abutment: Foundation Depth	River Bank Protection around Bri.
-	12	Sarawak	1988	-	8	-	straight	normal	enough	enough	oval shaped inverted T wall with exposed pile found. and round pile cap	enough	parallel	-	bank seat with pile found.	-	no
-	13	Sarawak	-	60.00	3	-	straight	normal	small	small	pile bent	small	parallel	-	RC wall with pile found.	-	not enough
-	14	Sarawak	-	-	-	-	straight	normal	enough	enough	oval shaped solid wall with pile cap and pile found.	enough	parallel	-	bank seat with pile found.	-	not enough
-	15	Sarawak	-	-	-	-	straight	normal	small	enough	rectangular solid wall with pile found.	enough	parallel	-	bank seat with pile found.	-	no
-	16	Sarawak	-	-	1	-	curve	skewed	small	small	-	-	-	-	rigid frame with concrete cylinder	-	no
-	17	Sarawak	-	-	3	-	curve	normal	enough	enough	pile bent with cylinder concrete pile	enough	parallel	-	RC rigid frame with cylinder concrete pile	-	no
-	18	Sarawak	-	-	3	-	straight	normal	small	small	square-pile bent	enough	parallel	-	bank seat	-	no
-	19	Sarawak	-	90.00	12	-	curve	normal	small	enough	octagonal steel pile bent	small	parallel	-	bank seat with octagonal pile found.	-	no
-	20	Sabah	1979	100.00	1	-	curve	normal	small	enough	-	-	-	-	RC wall	-	no
-	21	Sabah	1994	20.00	1	-	curve	skewed	small	small	-	-	-	-	inverted T	-	not enough
-	22	Sabah	1962	-	-	-	curve	skewed	small	small	square-pile bent	small	parallel	-	bank seat with pile found.	-	no
-	23	Sabah	-	20.00	1	-	curve	normal	small	small	-	-	-	-	bank seat with pile found.	-	provided but damaged
-	24	Sabah	-	100.00	3	40.00	curve	skewed	small	small	solid wall with round piles	enough	skewed	-	RC wall with pile found.	-	no

Table E.4 Summary of Hydrological Condition of the Inspected Bridges in Sabah and Sarawaku (3/3)

FT No.	Bridge No.	State	Const. Year	Total Length (m)	Span		CONDITION OF BRIDGE										
					No.	Max. (m)	Crossing Condition		Bridge Opening		Pier				Abutment		River Bank Protection around Bri.
							River Course	Crossing	Width	Height	Type	Span Length	Direction to Flow	Foundation Depth	Type	Foundation Depth	
-	25	Sabah	-	20.00	1	-	curve	skewed	small	small	-	-	-	-	inverted T with pile found.	-	no
-	26	Sabah	1974	100.00	3	-	curve	normal	enough	enough	pile bent	enough	parallel	-	bank seat with pile found.	-	enough
-	27	Sabah	1989	90.00	-	-	straight	normal	small	enough	oval shaped solid wall with exposed PC pile and hexagonal pile cap	small	parallel	-	RC wall with PC pile found.	-	no
-	28	Sabah	-	-	6	-	curve	normal	small	small	round steel pile bent	small	skewed	-	pile bent and RC wall	-	not enough