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No. 54

AFRICAN DEVELOPMENT BANK
GOVERNMENT OF MAURITIUS

DETAILED DESIGN
OF
BEAU BASSIN - PORT LOUIS LINK ROAD

TECHNICAL SUPPORTING REPORT

SEPTEMBER 1980

Japan International Cooperation Agency

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PREFACE

In response to the request of the Government of Mauritius and African Development Bank, the Japanese Government has decided to make a detailed design of the new Link Road construction between Beau Bassin and Port Louis.

The Japan International Cooperation Agency (JICA) which is the executing organ of technical cooperation extended by the Japanese Government, dispatched a preliminary survey team headed by Mr. Kimio Chiba, Director, Construction Department, Construction College, Ministry of Construction to Mauritius in October 1977 to formulate the scope of work. Following the above team, a detailed design team headed by Mr. Hirokazu Ito was sent to Mauritius four times. In the meanwhile, the detailed design team conducted a field survey and had discussions with the engineers of the Ministry of Works of Mauritius. Detailed designing was made in Japan and the present report has been prepared.

It is my sincere hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between our two countries.

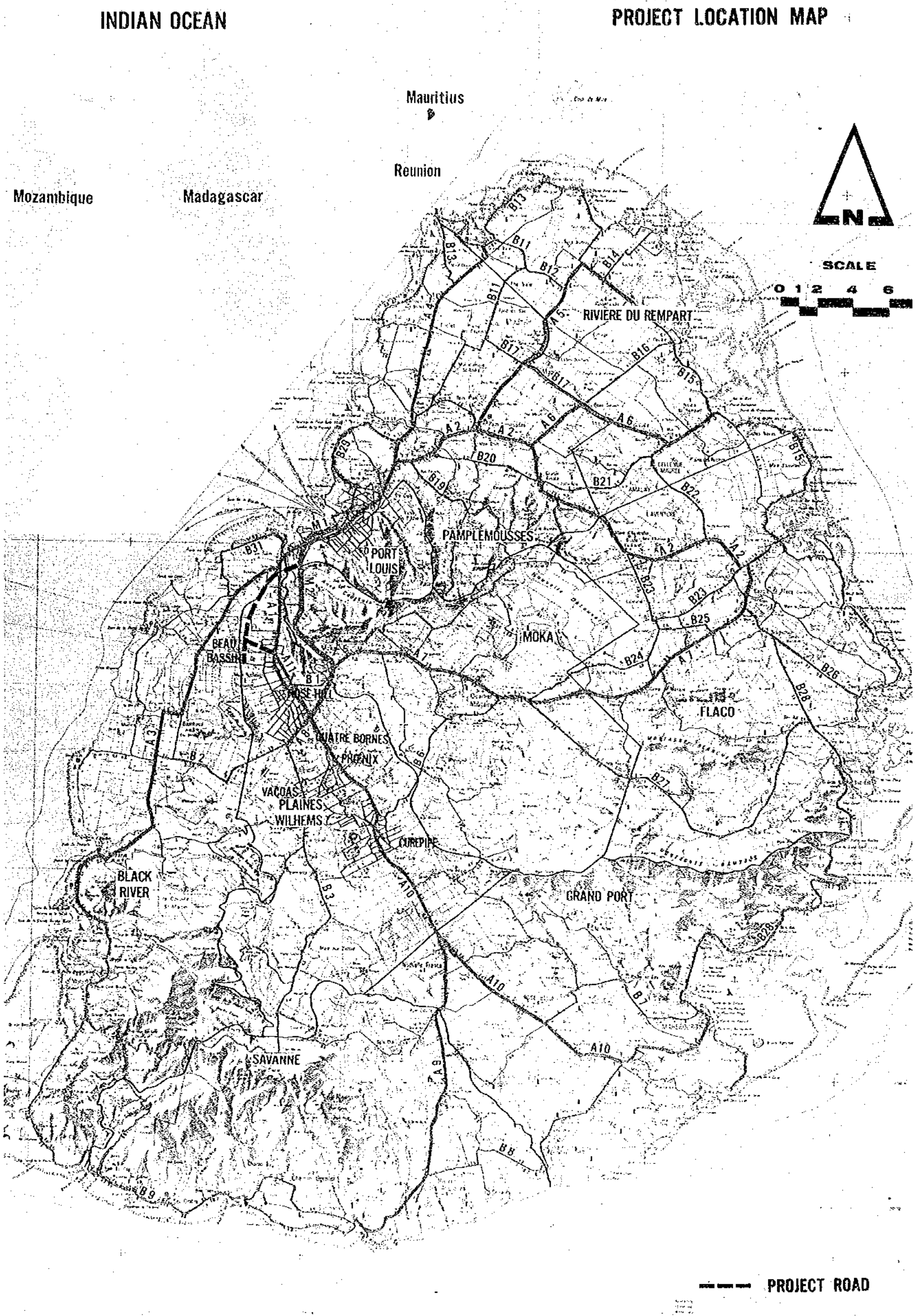
I wish to express my deep appreciation to all the officials and people concerned of Mauritius for their kind cooperation extended to our design team.

September 1980

Keisuke Arita

Keisuke Arita
President
Japan International Cooperation Agency

PROJECT LOCATION MAP



DETAILED DESIGN

OF

BEAU BASSIN - PORT LOUIS LINK ROAD

TECHNICAL SUPPORTING REPORT

TABLE OF CONTENTS

I. SUMMARY

The detailed design work on Beau Bassin - Port Louis Link Road (dual two-lane road) was carried out on the findings obtained in the course of the Feasibility Study, as endorsed by survey and geological soil tests, and it has been conducted through a series of conferences and consultation with the authorities concerned of the Mauritius Government. The process of the detail designing may be summarized as follows:

Selection of the Route has been made on the basis of the aerial photo grammetry map (1:1000 scale), being followed by the computation of horizontal alignment by use of electronic computers. Geological soil surveys have been effected by means of boring and test pits along the route; boring was undertaken by a local firm under the supervision of the consultants, and the soil samples obtained by boring and collected from the test-pits were tested at the Laboratory of Mauritius University as well as the Soil Laboratory of the Ministry of Works.

Profile leveling and cross-leveling were conducted along the center pegs which were driven in consideration of the computerized data. Design of the Road and Inter-Changes: Design of the plan, on the basis of the topographical map (1:1000) and design of the profile and the cross sections, on the basis of the profile and the cross sections prepared by actual surveys.

Bridges and small/medium structures have been designed on the reasonably enlarged plans, which were prepared from the topographical map of 1:1000 scale, using the design load and the loading was designed according to British standards. At the river-crossings, the substructures of the existing railway bridges are being utilized to reduce cost; superstructures of all the bridges are designed in terms of reinforced concrete girder or prestressed concrete girder; steel plate girder has not been adopted for economic reasons as well as the local conditions peculiar to Mauritius.

Drainage design has primarily been based on the results obtained from the hydraulic study, covering the meteorological data in the past, but it also reflects the peculiarities of Mauritius such as the existence of the irrigation canals towards sugar fields.

Estimation of the construction cost has been made after the unit-costs of construction materials, costs of the similar projects, and construction machinery costs, etc., have been assimliated in order to obtain the dominant features of the construction industry of Mauritius; taxes and duties being levied in Mauritius were also studied. Thus, the costs have been estimated component-wise (domestic, foreign and tax) and aggregated captgory-wise (by kind of construction work), according to the construction plan, by use of the unit cost analysis.

Tender documents have been prepared upon scrutinization of those concerning the similar projects in Mauritius, with necessary references to FIDIC, Specifications for Road and Bridge Works in UK, Guide Specifications for Highway Construction of AASHTO, Standard Specifications for National Expressways of JAPAN PUBLIC HIGHWAY CORPORATION.

Eventually, the dimensions of the projected road are as follows:

Roads

Main roads

Width = 24.40 m

Length = 7.6 Km

Beau Bassin access road

Width = 12.70 m

Length = 1.8 Km

Intersections

	3	Interchanges
	5	At-grade Intersections

Bridges

Main road bridges	4	bridges
Interchange bridges	11	bridges
Over bridges	5	bridges
Pedestrian bridges	2	bridges

II. FUTURE TRAFFIC VOLUME

The future traffic volume has been estimated on the following conditions:

2.01 The estimation of the future traffic volume on the project road is based on the report, "Beau Bassin - Port Louis Link Road Feasibility Study", prepared by Japan International Cooperation Agency (JICA).

2.02 A part of the generated traffic increased by the implementation of a revised Poine aux Sables Development Plan (population has been increased by 60,000 from 20,000) will be absorbed onto the project road. Because of difficulty in topographical conditions at S. Hill, accessibility towards Pointe aux Sables will be secured by the construction of the Coromandel junction linking between the industrial estates of Pointe aux Sables and Coromandel.

2.03 To construct three junctions, S. Hill junction, Coromandel junction and Richelieu Junction within the sectional length of 1.2 km makes it difficult to keep the project road highly standardized due to the complication of the traffic flow. Moreover, entrance and exit traffic volumes at the Richelieu Junction are mainly composed of the originating traffic from the Coromandel industrial estate. From the viewpoint of the safety of vehicle operation, the newly constructed Coromandel junction (a grade separation), which is directly connected with the Coromandel industrial estate, would be deemed usable for the originating traffic.

2.04 It is difficult to estimate the future traffic volume in detail at the Motorway junction because of an uncertain completion year for the Port Louis ring road. However, the estimation of the future traffic volume at the Motorway junction has been made on the following assumptions: The Motorway M_1 is running through the seaside area close to the central business district of Port Louis, while the Port Louis ring road is running through the outskirts of Port Louis, however, accessibility from the ring road to the central business district is worse than that from Motorway M_1. Accordingly, the ratio of the traffic volume from the project road to Motorway M_1 to that from the project road to the Port Louis ring road is assumed to be 6 to 4. The same ratio is applied to the traffic volume from Motorway M_2 to Motorway M_1 in comparison with that from Motorway M_2 to the Port Louis ring road. Furthermore, the values estimated by M.A.T.I.M. for the total entrance and exit traffic volumes towards Port Louis are used for estimating the future traffic demand at the Motorway junction in 2002.

2.05 Further southward extension of the project road from Beau Bassin would be deemed necessary. According to the report prepared by JICA, it is anticipated that the traffic congestion on the southward extension part of the A_1 road from Beau Bassin will reach a high level in 2002, thereby producing functional disturbances for the A_1 road. Completion of the project road up to Beau Bassin will contribute to relieve traffic congestion on the A_1 road running from Port Louis to Beau Bassin; however, the southward extension of the project road from Beau Bassin will be deemed necessary for relieving traffic congestion on the southward part of the A_1 road from Beau Bassin.

2.06 It is anticipated that after completion of the southward extension of the project road, the traffic volume at the Beau Bassin roundabout will fall to a lower level than estimated in the report prepared by JICA. Accordingly, the accessable traffic from the Beau Bassin roundabout is mainly made up of the originating traffic from Beau Bassin.

2.07 By taking account of the above-mentioned conditions, the future traffic volume on the project road will be estimated as follows:

Fig. II-1   Traffic Volume during the Morning Peak Hours : 1992

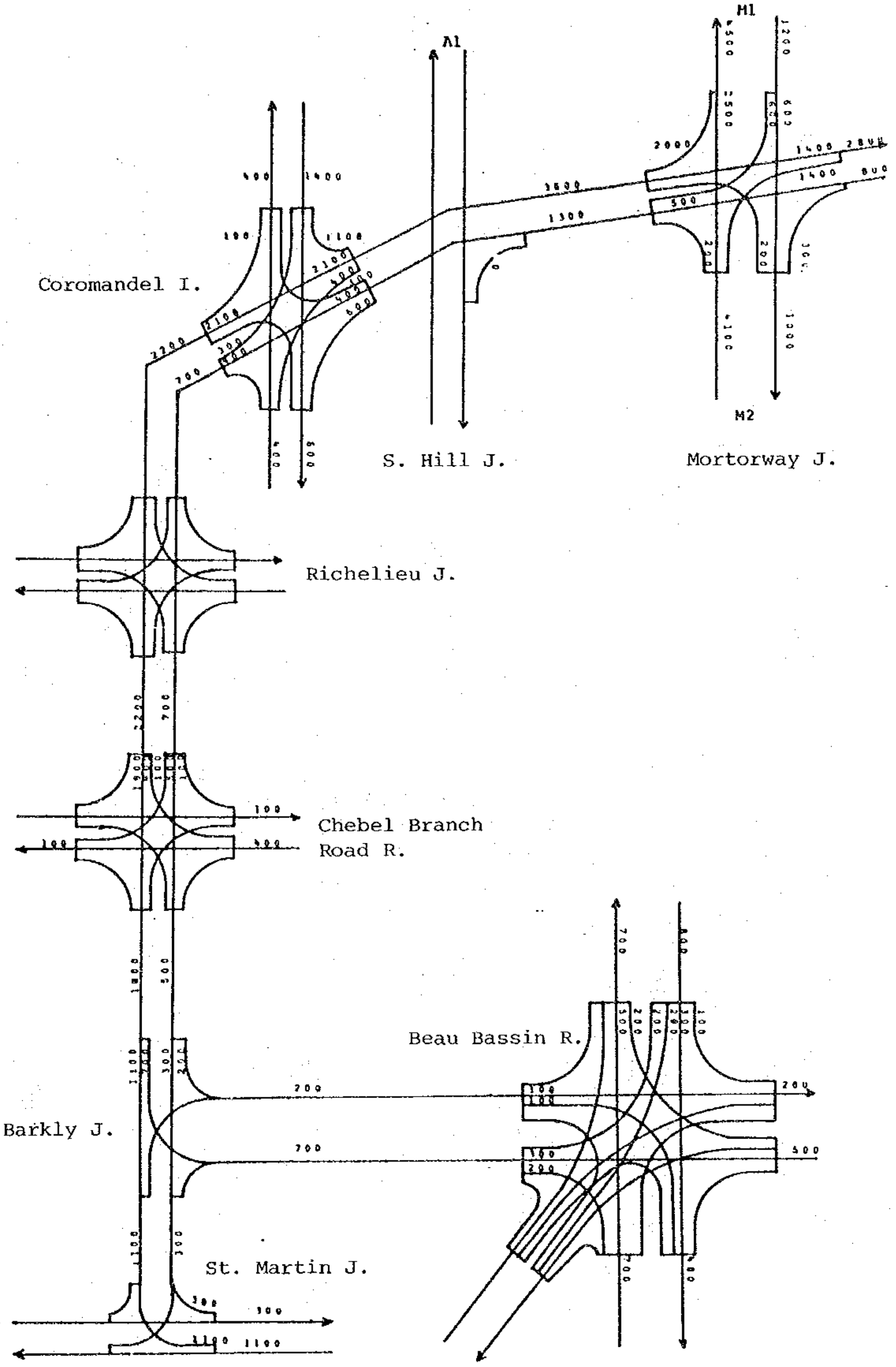


Fig. II-2 12-hour Traffic Volume : 1992

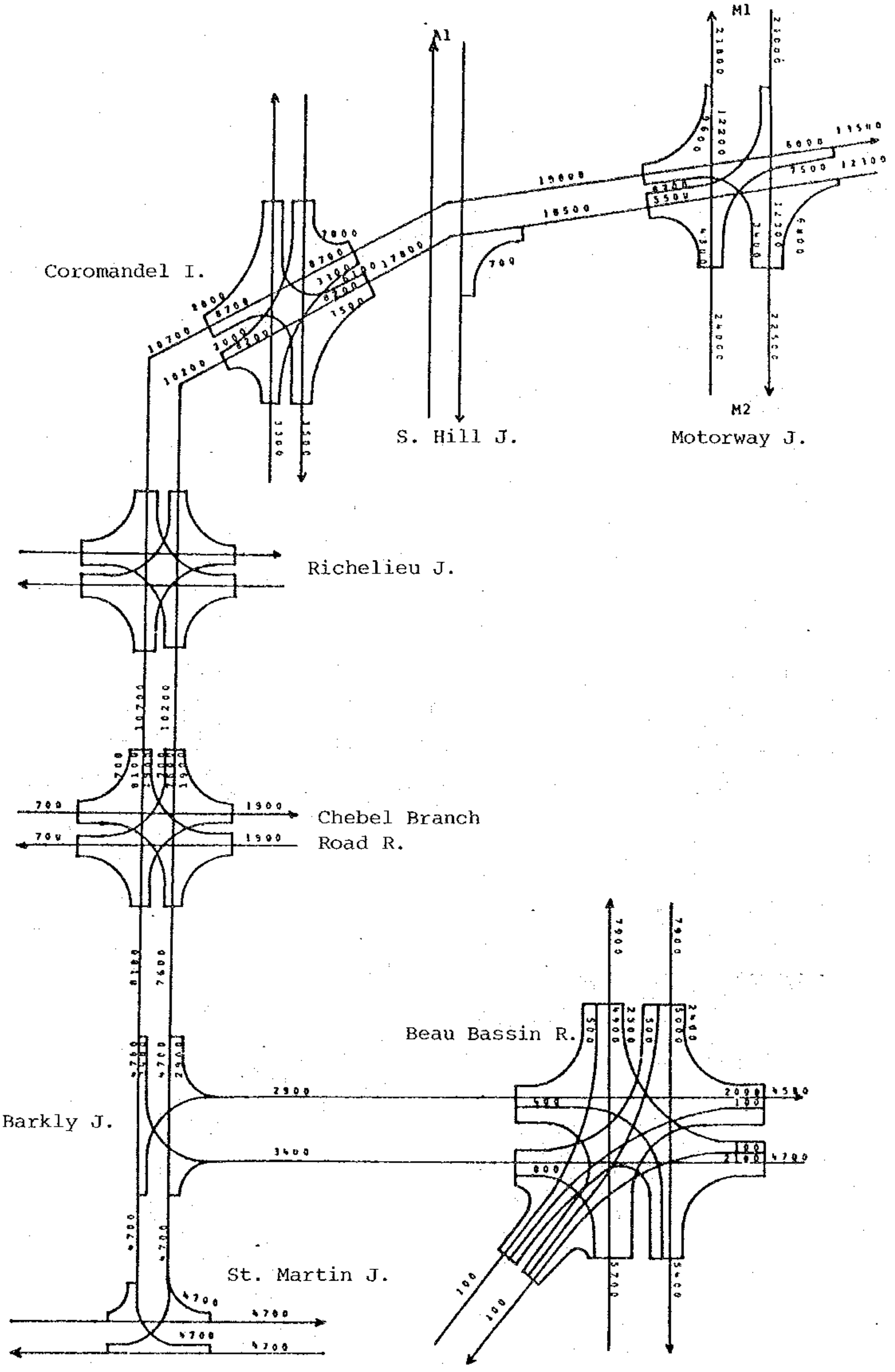


Fig. II-3 Traffic Volume during the Morning Peak Hours : 2002

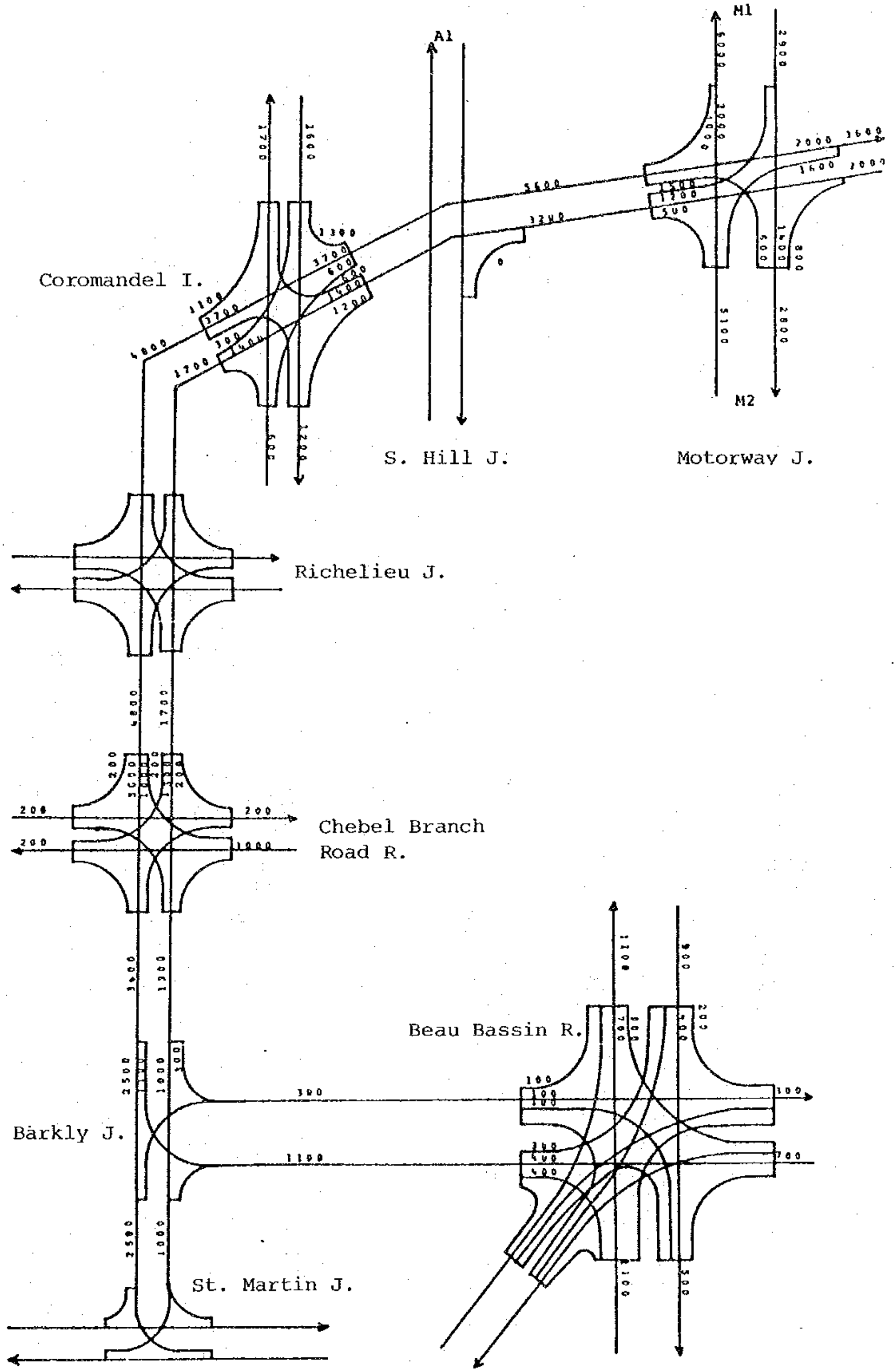
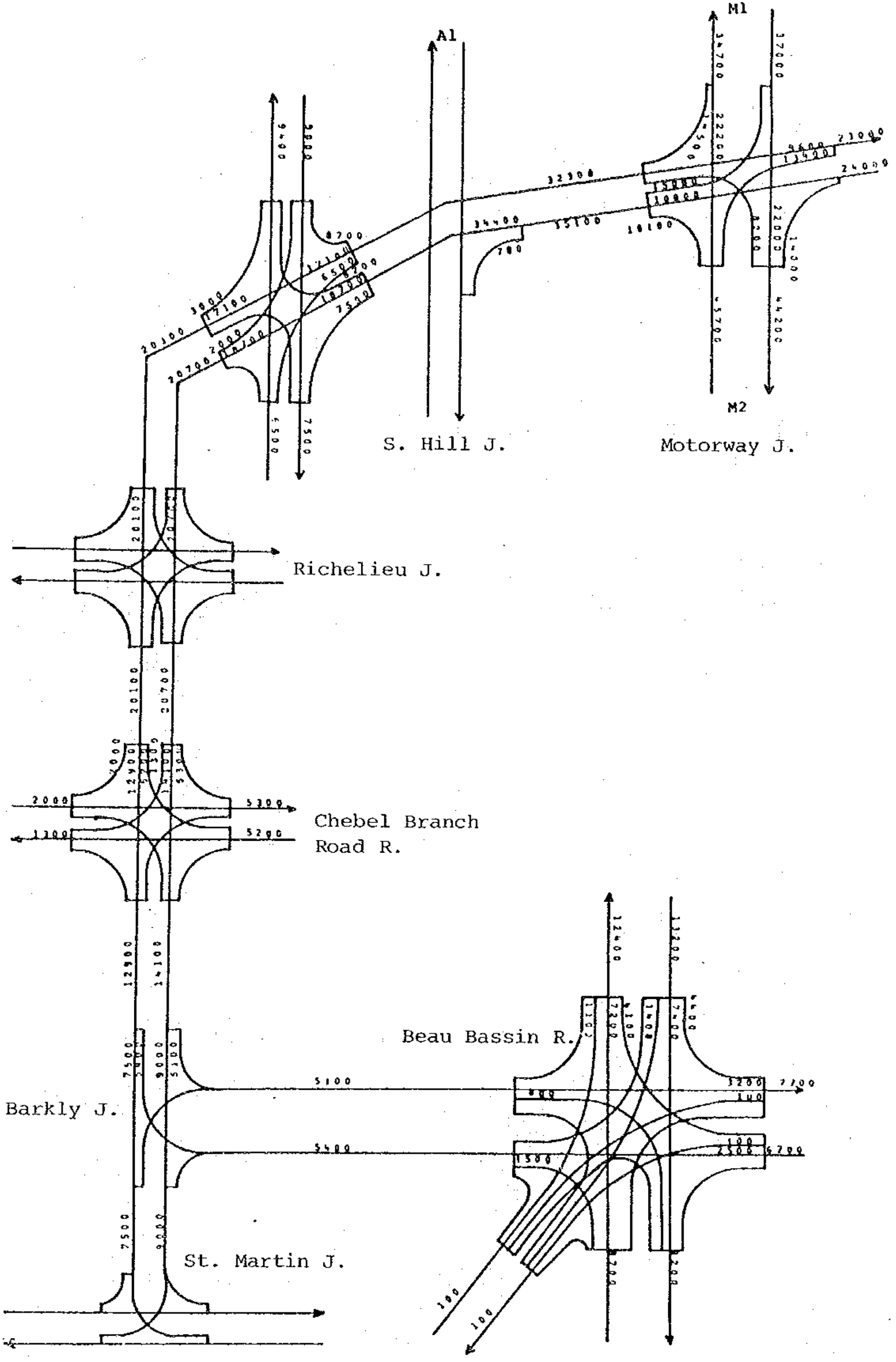


Fig. II-4 12-hour Traffic Volume : 2002



III. SURVEY

A. Purpose of Work

3.01 The alignment factors of road and interchanges have been computed, on the basis of the topographic map (scale 1:1,000) compiled by the aerial photogrammetric method with the result of our ground control survey carried out at the site from October to December, 1978.

3.02 In accordance with the data obtained from the above work, center line survey, profile level, cross-section survey and detailed topographic survey was executed.

B. Scope of Work

1. Traversing

3.03 For the establishment of the main points for center line survey, traversing were carried out along the route, relating to the National Control Points of Mauritius and control points established by our previous survey work.

2. Center Line Survey

3.04 Relating to the main points, center pegs were established at the interval of 20 meters.

3.05 Main points of concrete monuments were driven into the ground and center pegs were of steel or wood.

3. Profile Level

3.06 Profile level was carried out by observing center pegs, datum levels and distinct break in slope.

3.07 The observation was started from one bench mark and connected to another one. As for the river, a depth survey was carried out.

4. Cross-section Survey

3.08 The cross-section survey was carried out for the distance of 50 meters toward each side across the center line at a right angle. Measurement was done relating to the existing height of center pegs.

5. Detailed Topographic Survey

3.09 As for the Beau Bassin roundabout design, detailed topographic survey was carried out using a planetable.

C. Equipment to be Used

Electoromagnetic-wave distance meter	1 set
Second order transit	3 sets
Second order level	3 sets
Planetable	1 set

D. Final Results

3.10 In the end, the following final results were compiled from all data obtained.

a. Profile level (Polyester base)
H = 1/1.000, V = 1/200

b. Cross section (Polyester base)
H = 1/200 V = 1/200

c. Detailed topographic map
S = 1/200

IV. GEOLOGY AND SOIL SURVEY

CONTENTS

IV. GEOLOGY AND SOIL SURVEY

A. Outline of the Surveys

4.01 The surveys, surface geological survey, core boring, standard penetration test, test pit, soil test and rock test at the places along the planned route connecting Beau Bassin and Port Louis were conducted from 20th January to 19th March, 1979.

4.02 The site of the surveys are shown on Fig. IV-1, and their item and quantity are shown as follows:

Table IV-1 Field Work

Work Item	Number of Point	Total Depth (m)	Sampling	Location of Work
Core Boring	25	261.6	All Core	Proposed bridge site
Standard Penetration Test	47	-	-	Proposed bridge site
Test Pits	7	11.8	14	Proposed route
Surface Geological Survey	-	-	-	The area along the proposed route

Table IV-2 Laboratory Test

Test Item	Soil	Rock	Total
Specific Gravity	7	5	12
Natural Water Content	7	5	12
Grain Size Analysis	7	0	7
Atterberg Limits	7	0	7
Compaction Test	7	0	7
C.B.R. Test	14	0	14
Unconfined Compression Test	0	5	5
Direct Shear Test	7	0	7
Natural Density Test	7	5	12

B. Results and Consideration of the Survey

1. Geology along the Projected Route

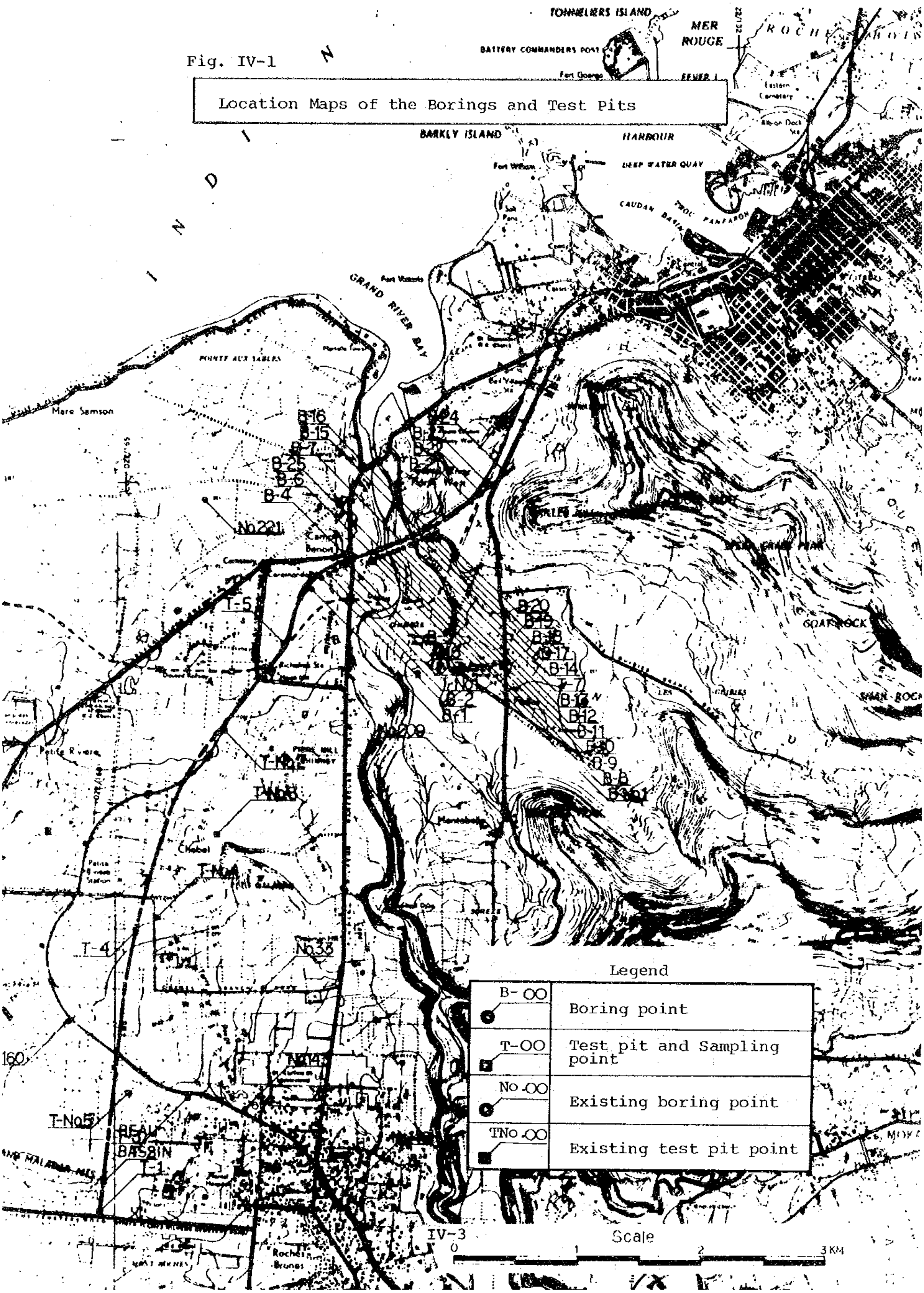
4.03 Geology along the projected route is as shown in Geological Map and Geological Section A-A', B-B' which are contained in the contract documents Volume C.

4.04 Strata underlying the projected route are composed of the older lavas which is a base-rock of mountainous district or plateau, the younger lavas composed of plateau, river terrace deposits on the terrace, and superficial deposits.

4.05 The older lava is a base rock of the strata underlying the projected route. The older lava are mainly Oliven-Basalt vomitted in the early tertiary period or older period with some Pyroclastic sediment.

Fig. IV-1

Location Maps of the Borings and Test Pits



The oliven-basalt as the main rock is dark gray or black and gran and very hard, has many cracks, joints and some voids. This stratum is found on both sides of G.R.N.W. and St. Louis River.

4.06 It has been observed that the older lava showing dark or jet gray colour consists mainly of oliven-basalt, and is considerably hard in quality and vesiculated.

4.07 Good conditioned outcrops of the lava is observed in both banks of the Grand River N.W. and St. Louis River.

4.08 This lava is observed at the boring sites of B. 1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 14, 16, 17, 18, 19, 20. The upper layer of this lava is estimated to exist at the depth of 5 to 20m below ground level. It has been observed that the strike of this lava is NE-SW, and the dip is 10° NW.

4.09 It is reported that the younger lava is the outcome of eruptions of the shield volcano in the Pliocene era or early period of Quaternary Diluvialera, and has formed a great lava plateau.

4.10 The Lava plateau in the civinity of the surveyed area consists of lava flows from the Curepipe Point, the lava being thickest at Plaines Willhems. The lava consists mainly of vesiculated oliven-basalt and dolerite; they are formed of magma accompained by a high liquidity and volatility.

4.11 The distribution of pillow lava, which was formed when lava flowed into water, is observed in the vicinity of both the Grand Rover N.W. and the St. Louis River.

4.12 Oliven-basalt and dolevite and hard, but they have been weathered and softened very much along many cracks and joints. The unweathered portion assumes a dark gray colour but alot of the weathered portion assumes brown colour.

4.13 Pillow lava is highly weathered, reddish brown or brown with soft rocks, and some has turned to soil.

4.14 Detritus deposits are distributed at the lower part of Mr. Grand Malabar, Mr. Petit Malabar, Pailles Hill and the lower part of the slope connecting the Grand River North west or St. Louis River and the adjacent highland.

4.15 The detritus deposit consists of gravels with sand, silt and clay. A lot of gravel is found at the upper part of the slope and its diameter is larger.

4.16 The gravel content is higher at the upper part of the slope and its diameter is large.

2. Foundation Rock at Bridge Construction Sites

4.17 Geological investigation has been performed at the disused railway bridge and at the new bridge construction site in order to examine the foundation rock. Results of these examination are shown in the Geological Map and Geological Section which are contained in the contract documents Volume C. Results of core boring are shown in the Geological Record of Boring.

a. St. Louis River Bridge

4.18 Geology of this site consists of the older lava (Basalt) as base rock and younger lava (pillow lava) on the old lava. Detritus deposits are found at the slope connecting the river bed and the adjacent highland.

b. Grand River North West Bridge

4.19 Geology of this site consists of the old lava (basalt) as base rock and young lava (pillow lava) on the old lava.

4.20 According to the boring core, the older lavas are hard, highly vesiculated and also highly cracked. Judging from the result of the standard penetration test, the N value of 50 implies that there exists no problem arising from the lava as far as the foundation rock of structures is concerned.

4.21 Boring core and outcrop-observation indicates the thickness of the river terrace deposits on the banks of G.R.N.W. as 4.3m on the left and 5.9m on the right. Being composed of gravel, sand, silt and clay, that on the left bank consists primarily of the round-shaped gravel ranging from 5 to 10cm in diameter, while that on the right bank, of sandy clay. N value of these layers which reads above 30 seems to be deceptive or an exaggerated value because of the mixture of gravel these layer are judged to lack enough bearing power and are unqualified as the foundation rock for heavy structures.

4.22 The river deposits are mainly composed of basalt in the shape of the large-sized, round or semi-round gravels (maximum diameter being 1.3m); their gaps are being matrixed with fine-grained gravel, sand, silt and clay. This layer is highly compact, with N value of 750. As the foundation rock of the structures, it is believed to have enough bearing power, but it is probably not completely free from the risk of scouring.

4.23 The detritus deposits which are generally comprised of gravel, sand silt and clay are primarily composed of sandy clay in this locality, with a probable thickness of from 2 to 3m. Their N value is less than 20.

c. Pailles Over Bridge

4.24 The geological formation of this spot is describable as an overlapping of the younger lava (pillow lava) on the bed-rock of the older lava (basalt). The older lava (basalt) has been found spreading below elevation 32m from B-14 and the outcrop (9m below the present ground level). From the observation of the boring cores obtained therefrom, it has been found dark-gray in colour, very hard though slightly vesiculated, with well-developed hair-cracks, but not very much weathered. Its N value is above 50 and the layer will provide a reliable foundation-rock for structures.

4.25 The younger lava (pillow lava) looks brownish in colour, remarkably weathered and softened. From the observation of its boring core, it shows the appearance of clay mixed with gravel rather than rock. Its N value varies widely between 11 and 50 or more.

d. Coromandel Over Bridge

4.26 Here, the younger lava (basalt) is overlapping the older lava (basalt) that is the bed-rock. The older lava (basalt) is spreading below elevation 37m. Its layer is extremely hard, rarely cracked, and obtainable in the shape of undisturbed core-lod. Having N value above 50, there is little doubt of its bearing power as a foundation-rock of any structure. Younger lava (basalt) looks brownish in colour; it is highly affected by weathering, the more so in the upper part, and is extensively vesiculated and cracked. The upper-most part of its layer has been extremely weathered and turned into silty clay mixed with gravel, reddish brown in colour, through deterioration.

e. Hill Over Bridge

4.27 Here, the younger lava (pillow lava) is spreading on the bed-rock which is made up of the older lava (basalt). The older lava (basalt) spreads below elevation 35m (7.1 - 8.35m below the present ground level) (see B-5 and B-6). This layer looks dark-gray in colour, is very hard, slightly vesiculated, having hair-cracks, but not very much weathered. Younger lava (pillow lava) is in an advanced stage of weathering and has softened assuming brownish colours. According to the observation of its core and outcrop, it more often exists in a clayish condition (mixed with gravel) rather than in rock condition. In its upper-most layer with a depth if 2 - 3m, it has turned silky clay in reddish-brown colour through intensive weathering and deperioration.

f. Coromandel Junction Bridge

4.28 The older lava (basalt) is spreading below elevation 42.5 - 45.0m (see B-1 and B-2); its layer looks gray to dark-gray in colour, is very hard and, though vesiculated and cracked, is not very much weathered. Younger lava (basalt) has well-developed crack-joints and is very much vesiculated; weathering remains at its surface and its core is considerably hard. With N value above 50, there will be no major problem as to its bearing power as the foundation-rock of structures. In its upper-most part, for the thickness of 3.0 - 4.3m, it has turned into reddish-brown silty clay through deterioration due to weathering.

g. Motorway Junction Bridge

4.29 Geologically speaking, this spot is made up of three layers of the older lava (basalt) at the bottom; the younger lava (basalt) at the middle; and the detritus deposits, on the surface.

4.30 Judging from the neighbouring outcrops, the older lava (basalt) is presumed to be spreading below elevation 36m, although this is not confirmed in B-11, 22, 23, and 24.

4.31 The younger lava (basalt) is very much vesiculated and shows well-developed crack-joints in its upper-most layer; weathering is advancing inwards along the cracks but does not reach the core which remains considerably hard yet. With N. value above 50, this layer will stand as a foundation-rock for structures without any major problems.

4.32 Detritus deposit which is spreading with a thickness of 2.0 - 5.4m increases its thickness as it proceeds from B-21 to 22 and 24. Its layer largely consists of fine grains such as clay and silt and is supposed to be a secondary deposit formed by washed down detritus deposits.

4.33 At B-24, in particular, it contains less gravel and is found in a considerably softened condition due to saturation which must be attributable to a lack of gravels and the high level of ground water. The ground water level is situated on the surface at B-24, 3m below ground level at B-23, 3.5m below ground level at B-22, and lower than 5m from the ground level at B-21.

4.34 The ground water is found inside the younger lava (basalt) at B-23, 22, and 21, but as the detritus deposits are spreading above the ground water level, they are free from softening as is witnessed at B-24.

4.35 N value ranges between 6 and 12 at B-24, while it is around 16-17 at other points. At some spots along this layer, N value reads between 30 and 50 or above, but their readings are believed to be over-exaggerated due to the existence of gravel there. Since this layer has lower N values in general, and B-24 in particular, consolidation settlement may occur through embankment, it is judged to be unsuitable as a foundation-rock of structures.

3. Structure of the Existing Abutments and Piers

a. St. Louis River Bridge

4.36 The findings obtained by boring at the abutments of the disused railway bridge are as follows: The right bank abutment (at B-16) has been confirmed to be standing on the older lava (basalt) and the left bank abutment (at B-15) is also assumed to be standing on the older lava (basalt), although it could not have been confirmed as boring encountered with rail sunk in concrete at 11.95 - 12.0m depth and no further boring was possible.

4.37 The abutments are piled up with basalt blocks on their exterior, but consist of plain concrete inside.

4.38 The concrete part is extremely fragile as it is porous with many apertures. Basalt broken into an angular shape, sometimes as big as 30cm in diameter, is used as coarse aggregate, while white coral sand is employed as fine aggregate. Coral sand is extremely fragile, apt to crumble down into fine grains, and hardly obtainable in the form of rod core due to hydraulic pressure through boring.

4.39 The foundation-rock on which the abutments are standing is vesiculated with many hair-cracks and considerably softened at parts due to weathering, as far as we can judge from the boring test at B-16.

4.40 Generally speaking, however, the nature of the rock itself is hard (as is confirmed by its boring core being obtainable in the shape of undistrubed core-rod), with N value above 50, thus assuring reliability as the foundation-rock for structures.

b. Grand River North West Bridge

4.41 The abutments of the disused railway bridge, both on the left bank and the right, are standing on the foundation-rock which is the older lava (basalt) (see B-6 and B-7). The abutments are piled up with basalt blocks on their exterior but consist of plain concrete inside. The concrete part is very fragile as it is porous with many apertures. Basalt broken into an angular shape, sometimes as big as 20cm in diameter, is used as coarse aggregate, and while coral sand, as fine aggregate.

4.42 The second pier from the left is set into the present river bed to the depth of 6.8m and standing on the river bed deposits as its supporting foundation.

4. Filling Materials

a. Soils

4.43 Soils spreading along the projected road as identified through the surface survey may be classified into the following two groups for filling purposes:

(i) Heavily weathered rocks (pillow lava, tuff)

(ii) Silty clay colouring from reddish-brown to brown

4.44 Their samples, both those disturbed and undisturbed, which were obtained from the test-pits at representative spots are shown in Fig. IV-2 to Fig. IV-6. The relationships between the test-pit sample Nos. and the soil types may be shown as follows:

Soil Type (i) .... Samples Nos. T-2 and T-7

" " (ii) .... Samples Nos. T-1, T-3, T-4, T-5 and T-6

4.45 Soil Type (i) is spreading over in the neighbourhood of the Grand Malabar Hill and G.R.N.W. - St. Louis River. The heavily weathered tuff which is available near the Grand Malabar Hill is spreading in a limited scope of area and is obtainable in the form of cohesive soil. Pillow lava spreading in the neighbourhood of G.R.N.W. - St. Louis turns out to be clay mixed with gravels (with the maximum diameter between 20 - 30cm) when obtained after cutting.

4.46 Soil Type (ii) is spreading extensively onto the terraces along the projected road; in fact, the projected road runs almost entirely in its total length in the area which is made up of this type of soild. Its layer consists of soil whose hardness is due to drying shrinkage, containing gravel with a maximum diameter of 60cm. The gravel content increases as elevation increases.

b. Embankment Materials

4.47 The results of the soil test with the test-pit samples will be briefed as follows (their details are shown in Table IV-3 and Table IV-4):

Soil Type (i)

4.48 Natural Water Content (18.5 - 34.7%) is below the Plastic Limit (23 - 36%), but slightly higher than the Optimum Moisture Content (16.8 - 28.9%). Its Natural Ground Dry Density (1.32 - 1.79 g/m^3) corresponds to 90 - 95% of the Maximum Dry Density (1.44 - 1.88 g/m^3).

4.49 Judging from the above-mentioned properties, this rock is in a considerably advanced stage of weathering. Once excavated and rolled into embankment, this weathered rock crumbles into fine grains and presumably assumes an aspect akin to silty clay mixed with gravel. As it has high trafficability, however, it will cause no trouble when used as embankement material.

Soil Type (ii)

4.50 Its Natural Water Content (21.7 - 38.3%) is almost equal to or a little less than the Plastic Limit (27 - 41%), roughly corresponding to the Optimum Moisture Content (25.7 - 39.6%). Its Natural Ground Dry Density (1.28 - 1.60 g/m^3) corresponds to 92 - 99% of the Maximum Dry Density (1.30 - 1.57 g/m^3).

4.51 Mechanical analysis clarified its composition as 0.5 - 36.3% gravel, 3.8 - 51.0% sand, and 27.2 - 90.0% silt/clay. Being grouped into SC, SH, and MH (Unified Soil Classification Method), it can be safely used as embankment material, if care is excercised regarding the chang in its water contend due to rain, etc. This means that when it is used as filling material and rolled under, if its water content happens to be more than its natural water content, both the compaction efficiency and the traficability will suffer.

4.52 Excluding tuff which belongs to the Soil Type (i), any one of the Soil Types (i) and (ii) will have no substantial difference among them as embankment material. Since tuff (Soil Type (i)) exists only in a part of the projected alignment, the quality of the embankment material may be argued in terms of the Soil Type (ii). As a result of the above consideration which has been based on the soil test results, the following may be adopted as design values:

Natural Ground Wet Density : 1.77 - 1.95 t/m^3

Natural Ground Natural Water Content : 26 - 36% (average 34%)

Natural Ground Dry Density : 1.29 - 1.60 (average 1.34 t/m^3)

Targeted Construction Water Content : 31 ± 5%

Targeted Construction Dry Density
Road Body : 1.30 t/m^3
Road Bed : 1.44 t/m^3

Targeted Construction Wet Density
Road Body : 1.70 t/m^3
Road Bed : 1.89 t/m^3

Targeted Design C.B.R. Value
(no difference between cutting and embanking)
Soil Type (ii) : 7.5%

Angle of Internal Friction (filling material) : $\phi = 28°$

Cohesion (filling material) : 5.30 t/m^3

Conversion Ratio to Mass
Road Body : 1.03
Road Bed : 0.93

Table IV-3 SUMMARY OF SOIL TEST

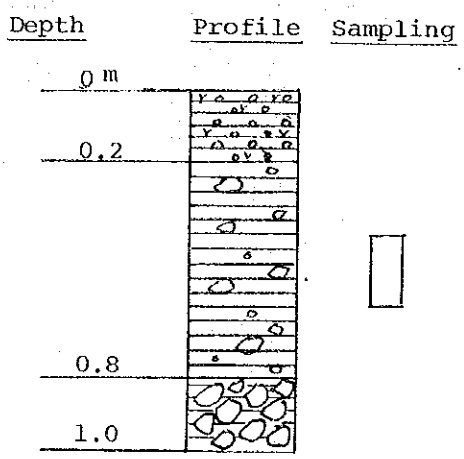
Test Item			Sample No.	T-1	T-2	T-3	T-4	T-5	T-6	T-7
Natural Water Content			(Wn:%)	21.7	18.5	38.3	33.5	35.0	35.9	34.7
Specific Gravity			(Gs)	2.815	2.896	2.721	2.859	2.835	2.953	2.826
Natural Wet Density			(γt:g/cm^3)	1.952	2.127	1.780	1.884	1.789	1.869	1.771
Natural Dry Density			(γd:g/cm^3)	1.604	1.794	1.287	1.411	1.325	1.376	1.315
Natural Void Ratio			(e_o)	0.754	0.614	1.114	1.016	1.140	1.146	1.149
Degree of Natural Saturation			(Sr:%)	81.0	87.3	93.5	94.3	87.0	92.5	85.3
Grain Size Analysis	2.0mm < Ds		(%)	36.3	6.1	0.5	16.5	3.8	3.9	48.0
	2.0mm - 0.074mm		(%)	36.5	54.2	3.8	19.9	51.0	6.1	13.4
	0.074mm > Ds		(%)	27.2	39.7	95.7	63.6	45.2	90.0	38.6
Atterberg Limits	Liquid Limit		(LL:%)	49	37	68	55	58	67	58
	Plastic Limit		(PL:%)	27	23	39	32	41	35	36
	Plastic Index		(Pl:%)	22	14	29	23	17	32	22
Compaction Test	Maximum Dry Density		(max γd:g/cm^3)	1.578	1.879	1.298	1.439	1.446	1.458	1.443
	Optimum Water Content		(Wopt:%)	25.7	16.8	39.6	32.5	33.6	30.7	28.9
Direct Shear Test	Internal Friction Angle		(ϕ: °)	42°00'	35°00'	41°00'	30°00'	30°00'	29°00'	34°30'
	Cohesion		(C:Kg/cm^2)	0.90	0.66	0.92	0.57	0.62	0.50	0.56
C.B.R. Test	California Bearing Ratio (CBR : %)	Undisturbed		83	32	74	11.4	8.2	10.7	25.1
		Disturbed		3.9	7.9	12.7	11.5	6.9	12.7	22.8
	Expansion Content (EC : %)	Undisturbed		1.4	1.4	0.4	0.2	1.3	1.7	0.2
		Disturbed		0.8	0.4	0.9	0.6	0.6	0.7	0.2
Classification (ASTM D2487-66T)				SC	SC	MH	MH	SM	MH	GM

Table IV-4 RESULT OF ROCK TEST

Sample No	B - 7	B - 8	B - 12	B - 18	B - 19
Sample Depth(m)	13.5-13.7	5.80-5.95	14.3-14.6	3.4-3.6	7.4-7.6
Natural (A) Weight (g)	2,475.8	1,458.0	1,775.8	1,135.5	898.0
After Saturation (B) Weight (g)	2,485.0	1,492.9	1,804.4	1,151.6	928.2
In Water (C) Weight (g)	1,609.1	882.3	1,152.0	719.0	529.4
After Dry (D) Weight (g)	2,455.7	1,441.9	1,768.6	1,131.0	875.6
Natural Density $\frac{(A)}{(B)-(C)}$ (g/cm^3)	2.827	2.388	2.722	2.625	2.252
Dry Density $\frac{(D)}{(B)-(C)}$ (g/cm^3)	2.804	2.361	2.711	2.614	2.196
Saturated Density $\frac{(B)}{(B)-(C)}$ (g/cm^3)	2.837	2.445	2.766	2.662	2.327
Natural Water Content $\frac{(A)-(D)}{(D)} \times 100$ (%)	0.82	1.12	0.41	0.40	2.56
Degree of Saturation $\frac{(A)-(D)}{(B)-(D)} \times 100$ (%)	68.6	31.6	20.1	21.8	42.6
Effective Porosity $\frac{(B)-(D)}{(B)-(C)} \times 100$ (%)	3.35	8.35	5.49	4.76	13.19
Absorption $\frac{(B)-(D)}{(D)} \times 100$ (%)	1.19	3.54	2.02	1.82	6.01
Specific Gravity $\frac{(D)}{(D)-(C)}$	2.731	2.577	2.868	2.745	2.529
Compression Strength (Kg/cm^2)	1,010.3	611.5	961.2	833.0	509.7

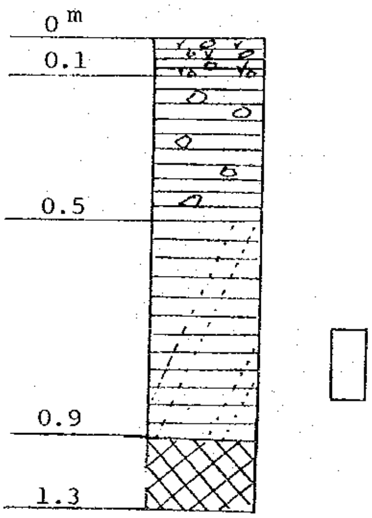
Fig. IV-2 SOIL PROFILE

T-1 (STA. 0+10)



Appearance	Condition
Dark gray sandy clay, organic matter and gravel mixture (ø5-15mm)	Dry and soft
Dark reddish brown sandy clay and much gravel mixture (ø5-40mm)	Dry and hard
Dark reddish brown gravel and sandy clay mixture (gravel max. size 600mm) gravel > sandy clay	Dry and very hard

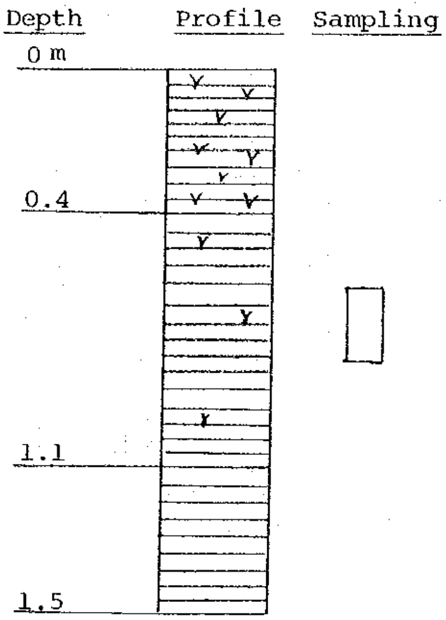
T-2 (STA. 2+70)



Appearance	Condition
Dark reddish brown clay with organic matter and gravel mixture (ø5-40mm)	Wet and soft
Reddish brown clay and gravel mixture (max. size 150mm)	Damp and stiff
Yellowish brown sandy clay (highly weathered tuff)	Humid and brittle
Yellowish brown weathered tuff	Soft rock

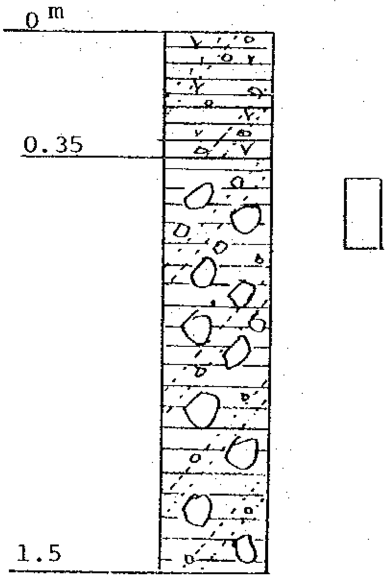
Fig. IV-3 SOIL PROFILE

T-3 (STA. 6+40)



Appearance	Condition
Dark brown silty clay and much organic matter mixture	Wet and soft
Reddish brown silty clay and a slight little bit organic matter mixture	Humid and hard
Reddish brown silty clay (many cracks)	Dry and very hard

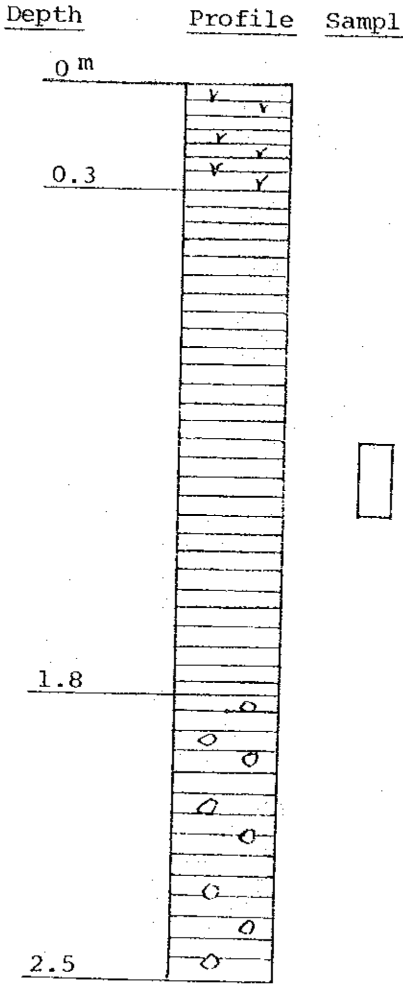
T-4 (STA. 22+35)



Appearance	Condition
Dark reddish brown sandy clay, much organic matter and gravel mixture (ø5-200mm)	Wet and soft
Dark reddish brown sandy clay and much gravel mixture(ø100-500mm)	Damp and hard

Fig. IV-4 SOIL PROFILE

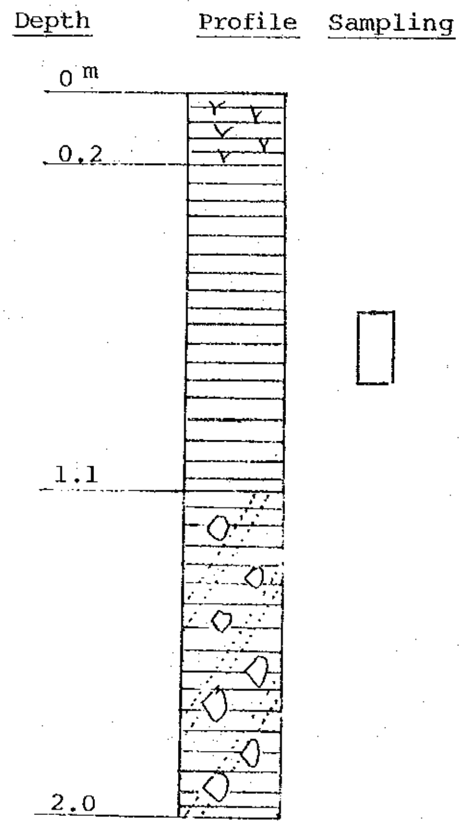
T-5 (STA. 48+40)



Appearance	Condition
Dark reddish brown silty clay and much organic matter mixture	Damp and soft
Reddish brown silty clay	Dry and hard
Reddish brown silty clay and soft gravel mixture (ø5-100mm)	Dry and very hard

Fig. IV-5 SOIL PROFILE

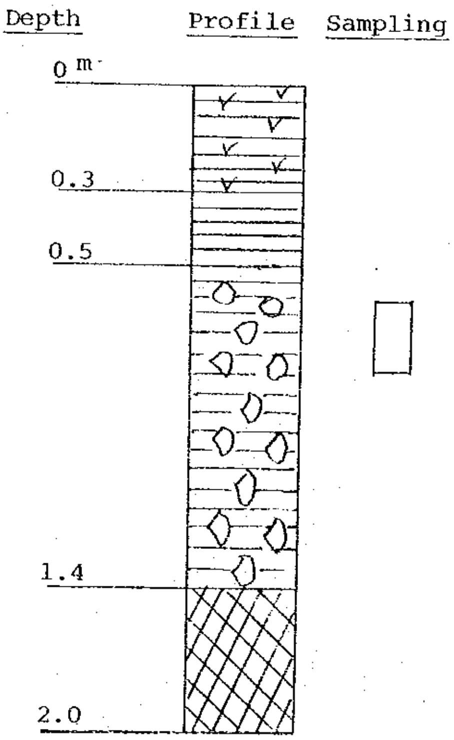
T-6 (STA. 58+60)



Appearance	Condition
Dark reddish brown silty clay and much organic matter mixture	Damp and soft
Reddish brown silty clay	Dry and hard
Brown sandy clay and much gravel mixture (ø5-200mm) (Highly weathered pillow lava)	Dry and very hard

Fig. IV-6 SOIL PROFILE

T-7 (STA. 64+40)



Appearance	Condition
Dark gray silty clay and much organic matter mixture	Wet and soft
Reddish brown silty clay	Damp and soft
Brown sandy clay and much gravel mixture (ø5-150mm) (Highly weathered pillow lava)	Dry and very hard
Brown weathered pillow lava	Soft rock

Fig. IV-7 **GEOLOGICAL RECORD OF BORING**

HOLE No. B-1

PROJECT	B. B - P. L - L. R. C. P	LOCATION	Colomandel Junction (STA 55+0)		
GROUND ELEVATION	52.50 M	DEPTH OF HOLE	10.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	76.2 mm	MACHINE	A	DATE OF DRILLING	3.2.78 — 3.2.78
CORE RECOVERY	99 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—		
		DRILLED BY	Gharburran	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION			
			COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
	3.0	3.0		Silty clay	Reddish Brown	• with a little bit gravel • Maximum Grain size 10mm • Dry and Hard (2.85m to 3.0m Concrete)
	4.60	1.60	v v v	Highly Weathered Basalt	Dark Gray & Brown	• Many vesicles • Many Cracks • Soft • Maximum Core Length 20 cm
	7.50	2.90	v v v	Weathered Basalt	Dark Gray	• Many vesicles • Many Cracks • Maximum Core Length 35 cm
	10.0	2.50	v v v	Basalt	Dark Gray	• Weathered in places • Many vesicles • Many Cracks • Maximum Core Length 24cm

CORE RECOVERY %	CORE RECOVERY cm	STANDARD PENETRATION TEST DEPTH (m)	(N)
	100	1.00	13/30
		1.30	
	100	2.00	19/30
		2.30	
	60	3.00	50<
	80	4.00	50<
	95	5.00	50<
	90	6.00	50<
	95	7.00	50<
	100	8.00	50<
	95	9.00	50<
	95	10.00	50<

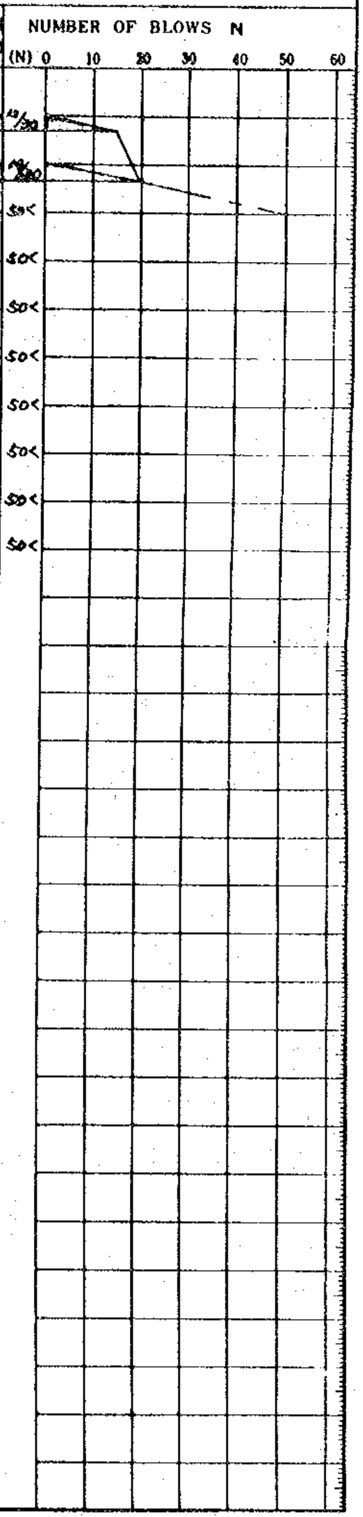


Fig. IV-8 GEOLOGICAL RECORD OF BORING

HOLE No. B − 2

PROJECT	B.B − P.L − L.R.C.P	LOCATION	Colomandel Juntion (STA 55+92)		
GROUND ELEVATION	50.2 M	DEPTH OF HOLE	10.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	76.2 mm	MACHINE	A	DATE OF DRILLING	1.2.79 — 2.2.79
CORE RECOVERY	97 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—		
		DRILLED BY	Ghurburrun	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
	0.40	0.40	v v v	Silty clay	D. Brown	· With Organic matter
	4.30	3.90		Silty clay	Dark Reddish Brown	· With a little bit Gravel · Maximum Grain size 6 mm · Dry and Very hard
	7.70	3.40	v v v	Weathered Basalt	Grayd Brown	· Flow structur · Many Vesicles · Many Cracks · Maximum Core Length 30 cm
	10.00	2.30	v v v	Basalt	Gray	· Very Hard · a little Vesicles · Maximum Core Length 30 cm

CORE RECOVERY %	DEPTH (m)	STANDARD PENETRATION TEST (N)
100	1.00	48/30
	1.30	
100	2.00	59/30
	2.30	
100	3.00	50<
100	4.00	60/30
	4.30	
80	5.00	50<
100	6.00	50<
100	7.00	50<
85	8.00	50<
96	9.00	50<
100	10.00	50<

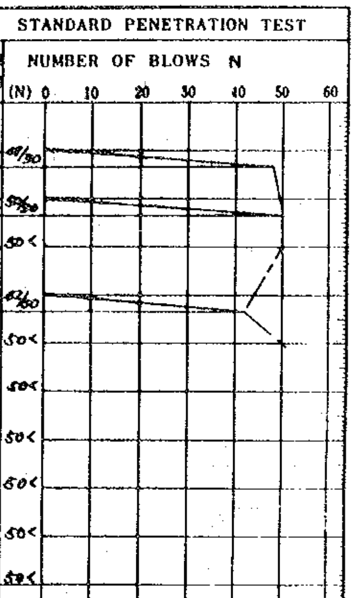


Fig. IV-9 GEOLOGICAL RECORD OF BORING

HOLE No. B-3

PROJECT	B. B. — P.L. — L.R.C.P	LOCATION	Colomandel Over Br. (STA57+47)
GROUND ELEVATION	48.0 M	DEPTH OF HOLE	10.0 M
ANGLE FROM VERTICAL	—	DIAMETER OF HOLE	76.2 mm
MACHINE	A	DATE OF DRILLING	30.1.79 – 31.1.79
CORE RECOVERY	90.5 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—
DRILLED BY	Ghurburrun	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION			
			COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
	3.34	3.34		Silty Clay	Reddish Brown	· with Gravel (Basalt) · Dry and Hard · Maximum Gravel Size 52mm
	7.25	3.91		Highly Weathered Basalt	Brown & Gray	· Very soft · Many Vesicles · Maximum Core Length 40cm
	9.00	1.75		Weathered Basalt	Dark Gray	· Vesicles · Hardness: Medium · Maximum Core Length 30cm
	10.00	1.00		Basalt	Gray	· Very Hard · A little Crucks · Maximum Core Length 28cm

CORE RECOVERY %	STANDARD PENETRATION TEST DEPTH (m)	(N)
100	1.00 1.20	69/20
100	2.00	50<
70	3.00	18/30
85	3.34 4.00	50<
90	5.00	50<
85	6.00	50<
85	7.00	50<
90	8.00	50<
100	9.00	50<
100	10.00	50<

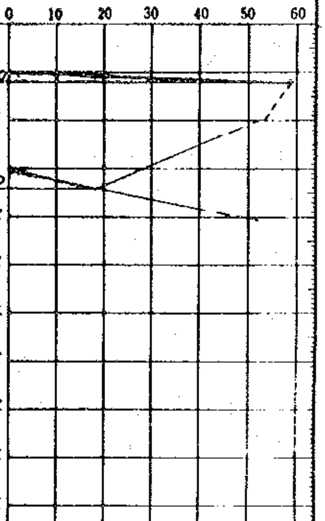


Fig. IV-10 GEOLOGICAL RECORD OF BORING

HOLE No. B-4

PROJECT	B.B - P.L. - L.R. C. P	LOCATION	S.Hill Over Br. (STA 58+94)		
GROUND ELEVATION	43.0 M	DEPTH OF HOLE	10.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	76.2 m	MACHINE	A	DATE OF DRILLING	10·2·79 — 12·2·79
CORE RECOVERY	78.5 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—		
		DRILLED BY	Ghurburun	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION: SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
	2.00	2.00	Fill Material	Dark Brown	· Gravel and Soil mix. · Gravel > Sand · Maximum Grain SIZE 10cm
	2.30	0.30	Silty Clay	Brown	Dry and Hard
	8.35	6.05	Highly Weathered Pillow lava	Dark Brown & Gray	· Very Soft · Many Vesicles · Maximum Core Length 10cm
	10.00	1.65	Weathered Basalt	Dark Gray	· Hard · Vesicles · Maximum Core Length 30cm

CORE RECOVERY cm	STANDARD PENETRATION TEST DEPTH (m)	(N)
80	1.00	
90	2.00	38/30
	2.30	
80	3.00	54/30
	3.30	
57	4.00	51/30
	4.30	
80	5.00	43/30
	5.30	
90	6.00	50<
90	7.00	50<
90	8.00	50<
100	9.00	50<
100	10.00	50<

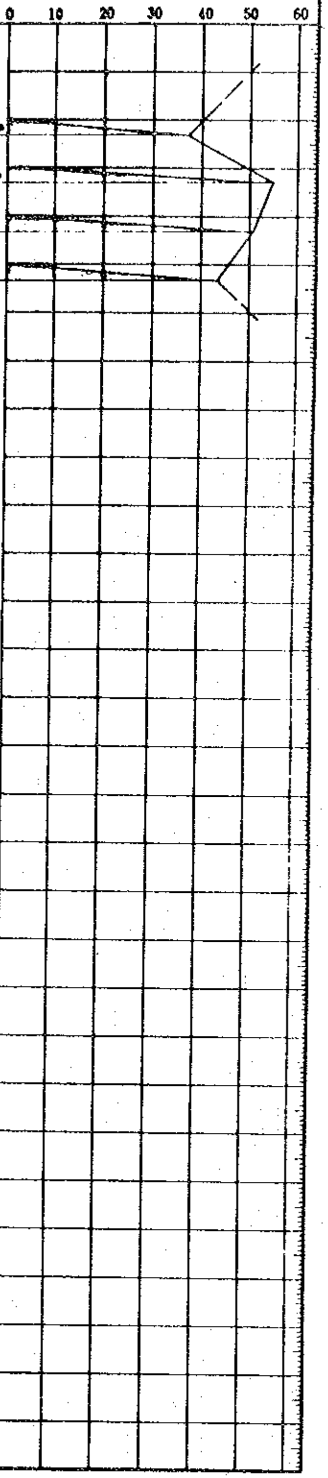


Fig. IV-11 **GEOLOGICAL RECORD OF BORING** **HOLE No.** B-5

PROJECT	B. B. — P.L. — L.R.C.P	LOCATION	S. Hill Over Br. (STA 58+88)		
GROUND ELEVATION	46.0 M	DEPTH OF HOLE	10.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	76.2 mm	MACHINE	A	DATE OF DRILLING	6.2.79 — 8.2.79
CORE RECOVERY	86.0 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—		
		DRILLED BY	Ghurburrun	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
	0.20	0.20		Silty Clay	D. Brown	With organic matter
	1.30	1.10		Silty Clay	Reddish Brown	· Wet and soft
	3.30	2.00		Highly Weathered Pillow Lava	Gray or Brown	· Very soft Rock · Can crush by finger · Many Vesicles · Maximum Core Length 5cm
	7.10	3.80		Weathered Pillow Lava	Gray or Brown	· Soft Rock · Highly weathered in places · Vasicles · Maximum Core Length 17cm
	10.00	2.90	v v v	Basalt	Dark Gray	· Hard Rock · A Little Vasicles · Maximum Core Length 25cm · Many cracks

CORE RECOVERY %	DEPTH (m)	(N)
100	1.00	7/30
	1.30	
40	2.00	33/20
	2.30	
50	3.00	5/30
	3.30	
90	4.00	51/30
	4.20	
85	5.00	50<
95	6.00	50<
90	7.00	50<
100	8.00	50<
100	9.00	50<
100	10.00	50<

STANDARD PENETRATION TEST

NUMBER OF BLOWS N

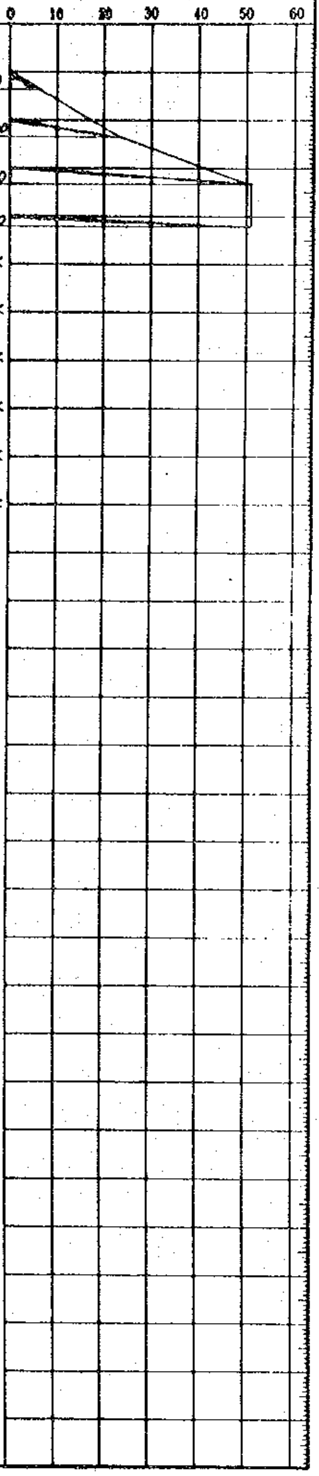


Fig. IV-12 GEOLOGICAL RECORD OF BORING

HOLE No. B-6

PROJECT	B·B· — P.L· — L·R·C·P	**LOCATION**	G·R·N·W· Br· (STA. 60+95)		
GROUND ELEVATION	34.41 M	**DEPTH OF HOLE**	11.0 M	**ANGLE FROM VERTICAL**	—
DIAMETER OF HOLE	76.2 mm	**MACHINE**	A	**DATE OF DRILLING**	16.2.79 — 20.2.79
CORE RECOVERY	50.0 %	**DEPTH TO GROUND WATER LEVEL IN HOLE**	—		
		DRILLED BY	Ghurburun	**LOGGED BY**	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION				CORE RECOVERY		STANDARD PENETRATION TEST	
			COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	%	cm	DEPTH (m)	NUMBER OF BLOWS N (N) 0 10 20 30 40 50 60
33.71	0.70	0.70		Blocks	Dark Gray	· Very Hard · Block of Basalt				
24.51	9.90	9.20		Concrete	Gray & White	· Porous · Maximum Core Length 65 · Maximum Aggregate size 15mm · Aggregate : Coral sand and Crushed Basalt		100 90 60 30 50 50 50 40 20		
23.41	11.00	1.10		Weathered Basalt	Dark Gray	· Hard Rock · Many cracks · Maximum Core Length 10cm		60 60	10.00 11.00	50< 50<

Fig. IV-13 **GEOLOGICAL RECORD OF BORING** HOLE No. B-7

PROJECT	B.B. — P.L. — L·R·C·P	LOCATION	G.R.N.W. Br. (STA. 62+89)		
GROUND ELEVATION	34.41 M	DEPTH OF HOLE	18.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	76.2 mm	MACHINE	D	DATE OF DRILLING	15.2.79 — 19.2.79
CORE RECOVERY	49.7 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—		
		DRILLED BY	B. Naidu	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
20.91	13.50	13.50		Concrete	Gray & White	· Porous · Maximum Core Length 20cm · Maximum Aggregate Size 20mm · Aggregate ; Coral Sand and Crashed Basalt
20.41	14.00	0.50		Basalt	Dark Gray	· Very Hard · Maximum Core Length 20cm
17.31	17.10	3.10		Highly Weathered Basalt	Brown & Gray	· Very soft Rock · Many vesicles · Maximum Core Length 10cm
16.41	18.00	0.90		Basalt	Dark Gray	· Very Hard · Maximum Core Length 50cm

CORE RECOVERY %	STANDARD PENETRATION TEST DEPTH (m)	(N)
80		
50		
65		
85		
30		
30		
50		
40		
60		
40		
50		
60		
40		
75	14.00	50<
20	15.00	50<
10	16.00	50<
20	17.00	50<
95	18.00	60<

NUMBER OF BLOWS N: 0 10 20 30 40 50 60

Fig. IV-14 GEOLOGICAL RECORD OF BORING

HOLE No.	B-8		
PROJECT	B.B. — P.L. — L.R.C.P	LOCATION	G.R.N.W. Br. (STA.61+22)
GROUND ELEVATION	11.68 M	DEPTH OF HOLE	7.0 M (6.0 M)
ANGLE FROM VERTICAL	—		
DIAMETER OF HOLE	76.2 mm	MACHINE	A
DATE OF DRILLING	3.3.79 — 7.3.79		
CORE RECOVERY	71.4 %	DEPTH TO GROUND WATER LEVEL IN HOLE	G.L. — 2.88 M
DRILLED BY	Ghurburrun	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
10.68	1.00	1.00	Sandy Clay	Reddish Brown	· with a little bit Gravel · Dry and Hard
8.33	3.35	2.35	Gravel & Sand	Dark Gray	· Gravel > Sand · Maximum Gravel size 85mm · Gravel ; Very Hard · Very Compacted
5.88	5.80	2.45	Gravel & Sand	Brown & Dark Gray	· Gravel > Sand · Maximum Gravel size 25mm · Gravel ; Very Hard · Very Compacted
4.68	7.00	1.20	Weathered Basalt	Dark Gray	· Very Hard · Many Vesicles · Maximum Core Length 30cm

CORE RECOVERY cm	DEPTH (m)	(N)
50	0.70 1.00	17/30
92	2.00	50<
99	3.00	50<
70	4.00	50<
60	4.50 4.80	23/30
40	5.00	50<
	5.30	16/30
90	5.60 5.80	50<

STANDARD PENETRATION TEST

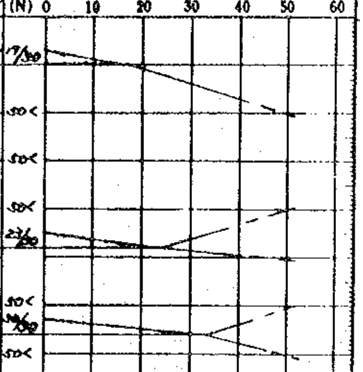


Fig. IV-15 **GEOLOGICAL RECORD OF BORING** **HOLE No.** B − 9

PROJECT	B.B. − P.L. − L.R.C.P		LOCATION	G.R.N.W. Br. (STA. 61+48)	
GROUND ELEVATION	8.86 M	DEPTH OF HOLE	8.0 M	ANGLE FROM VERTICAL	——
DIAMETER OF HOLE	63.0 mm	MACHINE	B	DATE OF DRILLING	14.2.79 − 5.3.79
CORE RECOVERY	40.6 %	DEPTH TO GROUND WATER LEVEL IN HOLE		G.L. −0.3 M	
		DRILLED BY	D. Henri	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION				CORE RECOVERY		STANDARD PENETRATION TEST	
			COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	%	cm	DEPTH (m)	NUMBER OF BLOWS N (N) 0 10 20 30 40 50 60
7.56	1.30	1.30		Sandy Claly	Brown	· with Gravel · Maximum Gravel size 10mm · Compact		60	1.00	50<
3.86	5.00	3.70		Gravel & Sand	Gray & Brown	· Gravel > Sand · Maximum Gravel size 30mm · Gravel : Very Hard · Very Compacted		85	2.00	50<
								70	3.00	50<
								70	4.00	50<
								20	5.00	50<
2.86	6.00	1.00		Gravel & Sand	Gray	· Large Gravel wish Sand · Max. Gravel size 50mm		40	6.00	50<
0.86	8.00	2.00		Gravel & Sand	Gray	· Gravel < Sand · Max. Gravel size 25mm · Very Compacted		10	200	50<
								25	8.00	50<

Fig. IV-16 GEOLOGICAL RECORD OF BORING

HOLE No.	B-10				
PROJECT	B.B. — P.L. — L.R.C.P	LOCATION	G.R.N.W. Br. (STA 61+76)		
GROUND ELEVATION	9.57 M	DEPTH OF HOLE	10.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	63.0 M	MACHINE	C	DATE OF DRILLING	1.3.79 — 13.3.79
CORE RECOVERY	95.5 %	DEPTH TO GROUND WATER LEVEL IN HOLE	G.L − 0.7 M		
		DRILLED BY	R. Gokhool	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
9.27	0.30	0.30	Silty Clay	Black	· Very soft
7.27	2.30	2.00	Gravel & Sand	Brown	· Gravel > Sand · Maximum Gravel Size 20mm · Compacted
6.17	3.40	1.10	Gravel	Dark Gray	· Max. Gravel Size 90mm · Gravel : very Hard
4.87	4.70	1.30	Gravel & Sand	Brown & Gray	· Gravel > Sand · Maximum Gravel Size 20mm · Very Compacted
-0.43	10.00	5.30	Gravel & Sand	Dark Gray	· Gravel > Sand · Maximum Gravel Size 100mm · Gravel : Very Hard · Very Compacted · Many Large Gravel

CORE RECOVERY %	STANDARD PENETRATION TEST DEPTH (m)	NUMBER OF BLOWS (N)
100	1.00	50<
100	2.00	50<
100	3.00	50<
95	4.00	50<
95	5.00	50<
95	6.00	50<
95	7.00	50<
90	8.00	50<
100	9.00	50<
95	10.00	50<

Fig. IV-17 **GEOLOGICAL RECORD OF BORING**

HOLE No. B－11

PROJECT: B·B — P.L — L·R·C·P

LOCATION: G·R·N·W· Br. (STA 62+2)

GROUND ELEVATION: 8.84 M

DEPTH OF HOLE: 10.0 M

ANGLE FROM VERTICAL: —

DIAMETER OF HOLE: 76.2 mm

MACHINE: A

DATE OF DRILLING: 24.2.79 — 28.2.79

CORE RECOVERY: 72.5 %

DEPTH TO GROUND WATER LEVEL IN HOLE: G.L ±0

DRILLED BY: Ghurburun

LOGGED BY: K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION: COLUMN SECTION	FIELD OBSERVATION: SOIL OR ROCK CLASSIFICATION	FIELD OBSERVATION: COLOUR	FIELD OBSERVATION: DESCRIPTION	CORE RECOVERY %	CORE RECOVERY cm	STANDARD PENETRATION TEST: DEPTH (m)	STANDARD PENETRATION TEST: NUMBER OF BLOWS (N)
				Gravel & Sand	Gray & Brown	· Gravel > Sand · Maximum Gravel size 25cm · Gravel : Very Hard · Compacted		80	1.00	50<
								50	2.00	50<
								30	3.00	50<
4.84	4.00	4.00						60	4.00	50<
				Gravel & Sand	Dark Gray	· Gravel > Sand · Maximum Gravel size 85cm · Gravel ; Very Hard · Very Compacted · Many Large Gravel		100	5.00	50<
								100	6.00	50<
								100	7.00	50<
0.84	8.00	4.00						95	8.00	50<
				Gravel & Sand	Dark Gray	· Gravel > Sand · Maximum Gravel size 30cm · Very Compacted		50	9.00	50<
-1.16	10.00	2.00						30	10.00	50<

NUMBER OF BLOWS N: 0 10 20 30 40 50 60

Fig. IV-18 GEOLOGICAL RECORD OF BORING

HOLE No. B-12

PROJECT	B.B — P.L — L.R.C.P	LOCATION	G.R.N.W. Br. (STA 62+28)		
GROUND ELEVATION	8.90 M	DEPTH OF HOLE	16.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	63.0 mm	MACHINE	C	DATE OF DRILLING	22.2.79 — 28.2.79
CORE RECOVERY	80.0 %	DEPTH TO GROUND WATER LEVEL IN HOLE	G.L ± 0		
		DRILLED BY	R. Gokhool	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
2.90	6.00	6.00		Gravel & Sand	Gray & Brown	· Gravel > Sand · Max. Gravel size 50mm · Gravel ; Very Hard · Very Compacted
-5.20	14.10	8.10		Gravel & Sand	Dark Gray	· Gravel > Sand · Max. Gravel size 120mm · Gravel, Very Hard · Very Compacted · Many large Gravel
-7.10	16.00	1.90	v v v	Basalt	Dark Gray	· Very Hard · A little Vecicles · Maximum Core Length 39cm

CORE RECOVERY %	cm	DEPTH (m)
	100	1.00
	95	2.00
	95	3.00
	90	4.00
	90	5.00
	85	6.00
	100	7.00
	90	8.00
	85	9.00
	90	10.00
	90	11.00
	80	12.00
	80	13.00
	50	14.00
	85	15.00
	85	16.00

STANDARD PENETRATION TEST

NUMBER OF BLOWS N

(N) 0 10 20 30 40 50 60

Fig. IV-19 **GEOLOGICAL RECORD OF BORING** HOLE No. B-13

PROJECT	B.B. — P.L. — L.R.C.P	LOCATION	G.R.N.W. Br. (STA 62+89)		
GROUND ELEVATION	26.70 M	DEPTH OF HOLE	10.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	63.0 mm	MACHINE	C	DATE OF DRILLING	16.2.79 — 20.2.79
CORE RECOVERY	84.0 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—		
		DRILLED BY	R. Gokhool	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
26.4	0.30	0.30	Silty Clay	Brown	With organic Matter
24.2	2.50	2.20	Sandy Clay	Brown & Dark Gray	· with Gravel (Maximum Size 20mm) · Dry and Hard
20.8	5.90	3.40	Sand clay & Gravel	Brown & Dark Gray	· Sandy Clay > Gravel · Maximum Gravel size 20mm · Core : Only Gravel. · Dry and compacted
20.0	6.70	0.80	Weathered Basalt	Dark Gray	· Many cracks · Maximum Core Length 10cm
17.5	9.20	2.50	Highly Weathered Basalt	Dark Gray & Brown	· Very soft Rock · Many Vesicles · Many cracks · Maximum Core Length 7cm
16.7	10.00	0.80	Basalt	Dark Gray	· Very Hard · Maximum Core Length 12cm

STANDARD PENETRATION TEST

DEPTH (m)	(N)
1.00	[illegible]
1.60	
2.30	47/30
2.60	
3.00	55/30
3.40	
4.00	[illegible]
4.30	
5.00	[illegible]
5.30	
6.00	50<
7.00	[illegible]
7.30	
8.00	50<
9.00	50<
10.00	50<

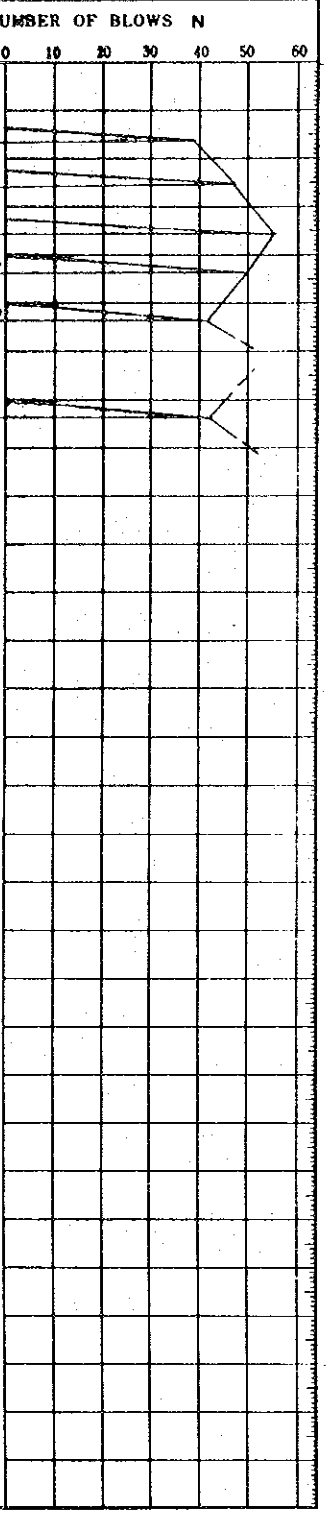


Fig. IV-20 GEOLOGICAL RECORD OF BORING

HOLE No. B-14

PROJECT	B.B — P.L — L.R.C.P	LOCATION	Pailles Over Br. (STA 64+49)		
GROUND ELEVATION	41.7 M	DEPTH OF HOLE	11.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	63.0 M	MACHINE	D	DATE OF DRILLING	11.2.79 — 14.2 79
CORE RECOVERY	69.5 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—		
		DRILLED BY	B. Naidu	LOGGED BY	A. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION: SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
	9.00	9.00	Highly Weathered Pillow Lava	Brown	· Very Soft Rock · Many Vesicles · From 0 to 4.0m; Gravel > Soil From 4.0 to 9.0m; Soil > Gravel · Maximum Core Length 10cm
	11.00	2.00	Basalt	Dark Grey	· Very Hard · Many Hair cracks · a little Vesicles · Maximum Core Length 12cm

COLUMN SECTION

CORE RECOVERY %	STANDARD PENETRATION TEST DEPTH (m)	(N)
90	1.00	50<
	1.50	11/30
80	2.00	19/30
	2.80	
50	3.00	50<
50	4.00	50<
	4.50	25/30
50	4.80	
50	6.00	31/30
	6.30	
100	7.00	50<
	7.50	19/30
100	7.80	
	8.00	50<
60	9.00	50<
60	10.00	50<
100	11.00	50<

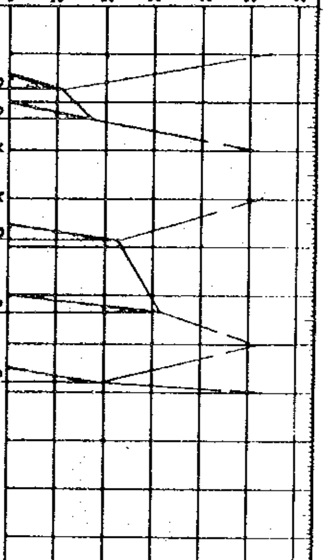


Fig. IV-21 GEOLOGICAL RECORD OF BORING

HOLE No. B − 15

PROJECT	B.B. − P.L. − L.R.C.P	LOCATION	St. Louis River Br. (STA 65+36)		
GROUND ELEVATION	34.4 M	DEPTH OF HOLE	12.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	63.0 mm	MACHINE	D	DATE OF DRILLING	7.2.79 —10.2.79
CORE RECOVERY	46.7 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—		
		DRILLED BY	B. Naidu	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION				CORE RECOVERY		STANDARD PENETRATION TEST	
			COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	%	cm	DEPTH (m)	NUMBER OF BLOWS N (N) 0 10 20 30 40 50 60
33.4	1.00	1.00			Gray	· Crushed Rock and Soil mixture. · Maximum size 10 cm		60		
25.9	8.90	7.90		Filled Material	Dark Brown & Gray	· Gravel and Soil Mixture · From 1.0 to 4.0 m Gravel > Soil · From 4.0 to 6.0 m Soil > Gravel · From 6.0 to 7.0 m Gravel > Soil · From 7.0 to 8.0 m Soil > Gravel · From 8.0 to 8.9 m Gravel > Soil · Maximum Gravel size 40 cm		55 65 40 20 10 40 20 30		
22.4	12.00	3.10		Concrete	Gray & Brown	· Porouse · Maximum Core Length 10 cm · Maximum Aggregate 10 cm · Aggregate : Coral Sand and Crushed Basalt · From 11.95 m to 12.0 m Steel		20 10 40		

Fig. IV-22 **GEOLOGICAL RECORD OF BORING** HOLE No. B − 16

PROJECT	B.B. −P.L −L.R.C.P		LOCATION	St. Louis River Br. (STA 65+64	
GROUND ELEVATION	34.4 M	DEPTH OF HOLE	20.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	63.0 mm	MACHINE	C	DATE OF DRILLING	12.2.79 — 15.2.79
CORE RECOVERY	97.5 %	DEPTH TO GROUND WATER LEVEL IN HOLE			
		DRILLED BY	R. Gokool	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION				CORE RECOVERY		STANDARD PENETRATION TEST	
			COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	%	cm	DEPTH (m)	NUMBER OF BLOWS N (N) 0 10 20 30 40 50 60
30.9	3.50	3.50		Blocks	Dark Gray	· Very Hard · Block of Basalt · Maximum core length 25cm				
17.0	17.40	13.90		Concrete	Light Brown	· Porous · Many Voids · Maximum Core Length 30cm · Maximum Aggregate size 80mm · Aggregate, Coral Sand and Crushed Basalt Mixture		90 90		
14.4	20.0	2.60		Weathered Basalt	Dark Gray α Dark Brown	· From 17.4 to 18.2m very Hard and Hair Crack · From 18.2 to 20.0m Soft and Many Vesicles · Maximum Core Length 20cm		90 90 90	18.00 19.00 20.00	50< 50< 50<

Fig. IV-23 GEOLOGICAL RECORD OF BORING

HOLE No. B - 17

PROJECT	B.B. — P.L. — L.R.C.P	LOCATION	St. Louis River Br. (STA.65+18)		
GROUND ELEVATION	25.96 M	DEPTH OF HOLE	7.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	76.2 mm	MACHINE	B	DATE OF DRILLING	5.2.79 — 7.2.79
CORE RECOVERY	99.3 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—		
		DRILLED BY	D. Henri	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION			
			COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
23.36	2.60	2.60	○ ○	Gravel & clay	Dark Gray or Brown	· Clay : Sandy clay · Gravel > clay · Maximum Grain size 22mm · Damp and Loose
21.96	4.00	1.40	☰	Silty Clay	Reddish Brown	· With Gravel a little · Maximum Grain size 1mm · Dry and Hard
20.66	5.30	1.30	v v v	Highly Weathered Basalt	Dark Brown	· Soft Rock · Many vesicles · Maximum Core Length 7cm
18.96	7.00	1.70	v v v	Weathered Basalt	Dark Gray	· Many cracks · vesicles · Maximum Core Length 20cm

CORE RECOVERY % cm

STANDARD PENETRATION TEST

DEPTH (m)	(N)
1.50 1.80	24/30
2.00 2.10	50/10
3.00 3.10	50/10
4.00 4.10	50/10
5.00	50<
6.50	50<
7.00	50<

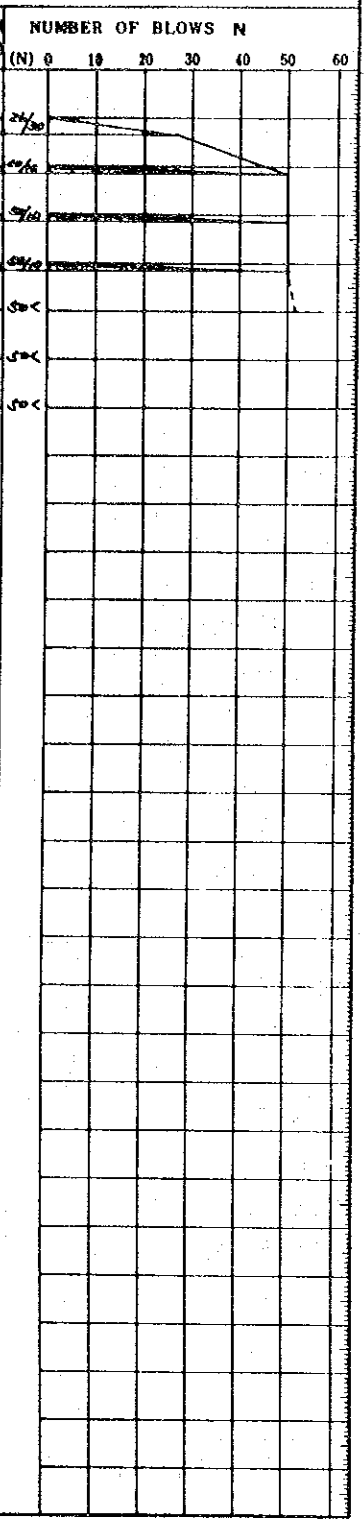


Fig. IV-24 GEOLOGICAL RECORD OF BORING

HOLE No. B — 18

PROJECT	B.B — P.L. — L.R.C P	LOCATION	St. Louis River Br. (STA. 65+43)		
GROUND ELEVATION	21.07 M	DEPTH OF HOLE	4.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	63.0 mm	MACHINE	B	DATE OF DRILLING	8.2.79 — 8.2.79
CORE RECOVERY	97.5 %	DEPTH TO GROUND WATER LEVEL IN HOLE	G.L. - 0.7 M		
		DRILLED BY	D. Henri	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION				CORE RECOVERY		STANDARD PENETRATION TEST	
			COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	%	cm	DEPTH (m)	NUMBER OF BLOWS N (N) 0 10 20 30 40 50 60
20.33	0.74	0.74		Sandy clay	Dark Blown	· Very Soft · With Organic matter		90	1.00	50<
18.37	2.70	1.96		Gravel & Sand	Dark Blown & Gray	· Gravel > Sand · Maximum Gravel size 50mm · Compacted		90	2.00	50<
17.07	4.00	1.30	V V V V V V V V	Basalt	Dark Gray	· Very Hard · A little Vasicles · Maximum Core Length 20cm		100	3.00	50<
								100	4.00	50<

Fig. IV-25 **GEOLOGICAL RECORD OF BORING** HOLE No. B – 19

PROJECT: B.B. — P.L — L.R.C.P
LOCATION: St. Louis River Br. (STA 65+74)
GROUND ELEVATION: 20.94 M
DEPTH OF HOLE: 12.0 M
ANGLE FROM VERTICAL: —
DIAMETER OF HOLE: 63.0 mm
MACHINE: C
DATE OF DRILLING: 8.2.79 — 9.2.79
CORE RECOVERY: 91.2 %
DEPTH TO GROUND WATER LEVEL IN HOLE: G.L. – 0.75 M
DRILLED BY: R. Gokhool
LOGGED BY: K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION			
			COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
20.24	0.70	0.70		Sandy Clay	Dark Brown	· Very soft · With Gravel (Maximum Size 25)
18.94	2.00	1.30		Sandy Clay & Gravel	Grayish Green	· Gravel > Clay · Maximum Gravel Size 10
16.94	4.00	2.00		Sand & Gravel	Dark Gray	· Gravel > Sand · Maximum Gravel Size 20 · Compact
13.94	7.00	3.00		Highly Weathered Basalt	Dark Gray & Dark Brown	· Depth 4.0~4.6 m and 5.0~7.0 m Very Soft and Many Vesicular, Maximum Core Length 5 cm · Depth 4.6~5.5 m Very Hard and vesicular
9.94	11.00	4.00		Basalt	Dark Gray	· Very Hard · Many Vesicular · Maximum Core Length 40

CORE RECOVERY %	STANDARD PENETRATION TEST DEPTH (m)	(N)
85	1.00	50>
100	2.00	50<
90	3.00	50<
90	4.00	50<
85	5.00	50<
80	6.00	50<
75	7.00	50<
80	8.00	50<
100	9.00	50<
90	10.00	50<
100	11.00	50<

NUMBER OF BLOWS N: 0 10 20 30 40 50 60

Fig. IV-26 **GEOLOGICAL RECORD OF BORING** HOLE No. B-20

PROJECT	B.B. — P.L. — L.R.C.P	LOCATION	St. Louis River Br. (STA 66+2)		
GROUND ELEVATION	26.95 M	DEPTH OF HOLE	12.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	63.0 cm	MACHINE	C	DATE OF DRILLING	5.2.79 — 7.2.79
CORE RECOVERY	92.9 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—		
		DRILLED BY	R. Gokhool	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
	0.70	0.70		Silty Clay	Dark Gray	·With organic matter
	3.80	3.10		Silty Clay	Reddish Brown	·With Gravel (Soft) ·Maximum Gravel Size 10cm ·Damp and Stiff
	8.30	4.50	V V V	Highly Weathered Basalt	Dark Brown	·Very Soft Rock ·Many Vesicles ·Maximum Core Length 10cm ·Many Craks
	12.00	3.70	V V V	Weathered Basalt	Dark Brown & Dark Gray	·Many Cracks ·Highly Weathered in places Many Vesicles ·Soft Rock ·Maximum Core Length 20cm

CORE RECOVERY cm	STANDARD PENETRATION TEST DEPTH (m)	NUMBER OF BLOWS (N)
100	1.00 1.30	11/30
100	2.00 2.30	24/30
100	3.23 3.53	37/30
100		50<
100	4.83 5.13	17/30
100	6.00	50<
100	6.60 6.90	34/30
100	8.00 8.30	38/30
90	9.00	50<
80	10.00	50<
25	11.00	50<
20	12.00	50<

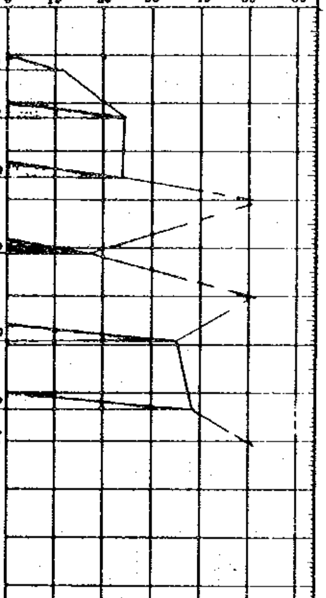


Fig. IV-27 GEOLOGICAL RECORD OF BORING

HOLE No. B - 21

PROJECT	B. B — PL — L.R.C.P	LOCATION	Moter Way Junction (STA. 69+88)		
GROUND ELEVATION	40.7 M	DEPTH OF HOLE	5.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	76.2 mm	MACHINE	B	DATE OF DRILLING	31.1.79 — 1.2.79
CORE RECOVERY	100 %	DEPTH TO GROUND WATER LEVEL IN HOLE	—		
		DRILLED BY	D. Henri	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION				CORE RECOVERY		STANDARD PENETRATION TEST	
			COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	%	cm	DEPTH (m)	(N)
	0.20	0.20		Clay	Brown	with organic matter				
	2.00	1.80		Clay	Dark Gray	· with Gravel · Maximum Gravel size 15mm · Damp and stiff		100	0.50 0.80 2.00	17/30 50<
	3.80	1.80		Weathered Basalt	Gray & Dark Brown	· Many cracks · Many Vesicles · Maximum Core Length 15cm		100	3.00 4.00	50< 50<
	5.00	1.20		Basalt	Dark Gray	· Hard Rock · a little vesicles · Maximum Core Length 25		100	5.00	60<

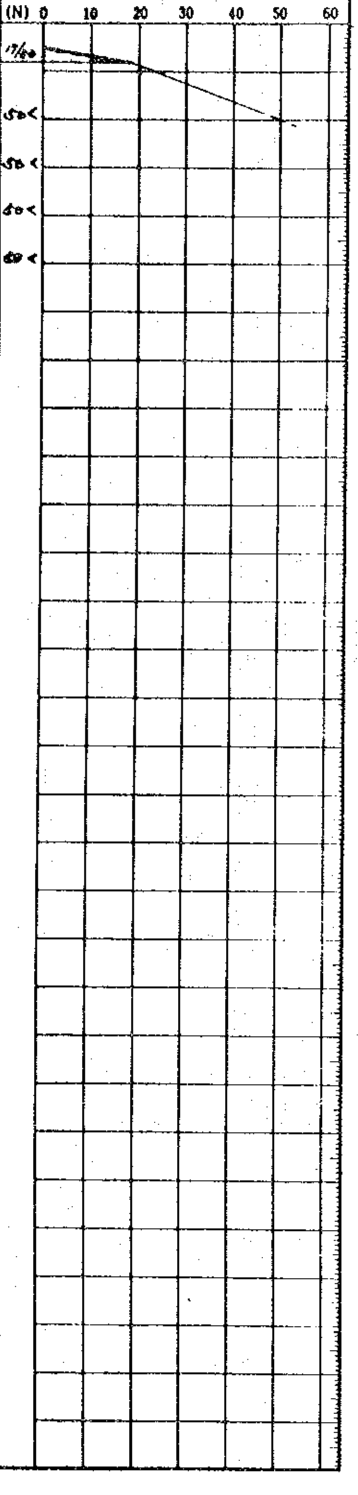


Fig. IV-28 GEOLOGICAL RECORD OF BORING

HOLE No. B - 22

PROJECT	B. B. - P. L. - L. R. C. P	LOCATION	Morter Way Junction (STA 71+2)		
GROUND ELEVATION	42.2 M	DEPTH OF HOLE	5.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	63.0 mm	MACHINE	B	DATE OF DRILLING	1.2.79 — 2.2.79
CORE RECOVERY	96.0 %	DEPTH TO GROUND WATER LEVEL IN HOLE	GL -3.5 M		
		DRILLED BY	D. Henti	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION: COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	CORE RECOVERY %	cm	STANDARD PENETRATION TEST: DEPTH (m)	(N)
	2.82	2.82		Gravel & Sandy Clay	Dark Brown & Gray	· Gravel > clay · Maximum Gravel Size 35 mm · Depth 1.8 - 2.8 m clay > Gravel · Damp and Stiff		[illegible] [illegible]	1.00 1.88 2.20	50< 37/30
	5.00	2.18	v v v v v v v v v v	Weathered Basalt	Dark Gray	· Many Vesicles · Hard Rock · Many cracks · Maximum Core Length 16 cm		[illegible] [illegible] [illegible]	3.00 4.00 5.00	50< 50< 50<

NUMBER OF BLOWS N

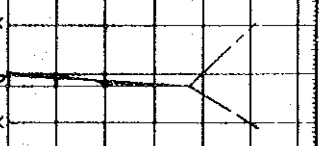


Fig. IV-29 **GEOLOGICAL RECORD OF BORING** HOLE No. B - 23

PROJECT	B.B. — P.L — L.R.C.P	LOCATION	Mortar Way Junctio (STA 71+97)		
GROUND ELEVATION	43.0 M	DEPTH OF HOLE	5.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	63.0 mm	MACHINE	B	DATE OF DRILLING	30.1.79 — 31.1 79
CORE RECOVERY	98.0 %	DEPTH TO GROUND WATER LEVEL IN HOLE	G.L -3.0 M		
		DRILLED BY	D. Henri	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION				CORE RECOVERY		STANDARD PENETRATION TEST	
			COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	%	cm	DEPTH (m)	NUMBER OF BLOWS N (N)
	0.70	0.70		Clay	Dark Gray	· With organic Matter and gravel.				
	3.00	2.30		Gravel & clay	Black & Dark Gray	· Gravel > Clay · Maximum Gravel size 15cm · Damp and stiff		100 100 95	1.00 2.00 2.30 3.00	50< 15/30 50/29
	5.00	2.00		Weathered Basalt	Dark Gray	· Many Vasicular · Many Cracks · Maximum Core Length 15cm		 28 100	3.29 4.00 5.00	 50< 50<

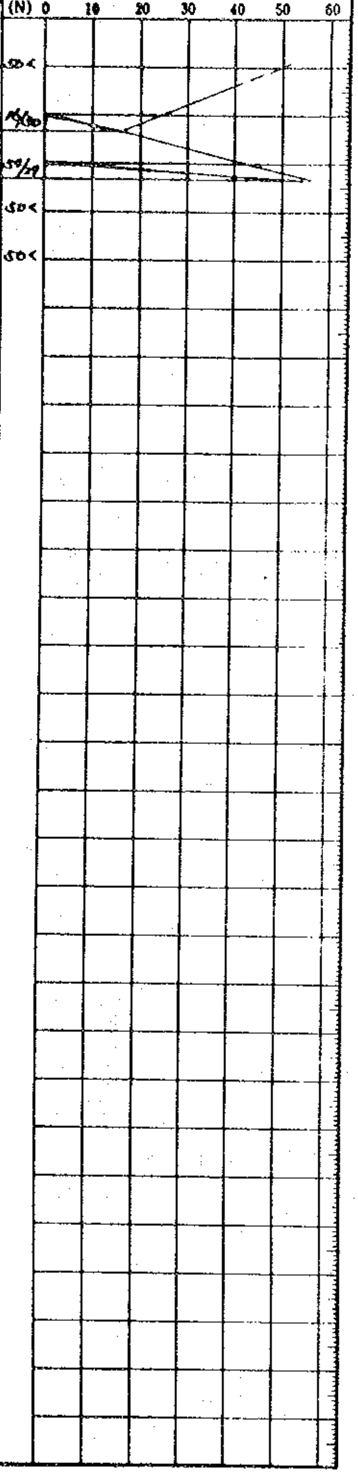


Fig. IV-30 **GEOLOGICAL RECORD OF BORING** HOLE No. B - 24

PROJECT	B.B — P.L — L.R.C.P	LOCATION	Moter Way Junction (STA 72+80)		
GROUND ELEVATION	44.0 M	DEPTH OF HOLE	7.0 M	ANGLE FROM VERTICAL	—
DIAMETER OF HOLE	63.0 mm	MACHINE	B	DATE OF DRILLING	10.2.79 — 12.2.79
CORE RECOVERY	94.3 %	DEPTH TO GROUND WATER LEVEL IN HOLE	G.L ± 0		
		DRILLED BY	D. Henri	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION: COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION
	1.00	1.00		Clay	Black	· Very Soft · With Organic Matter
	4.40	3.40		Clay	Grayish Black	· Very soft and wet · Very sticky
	5.40	1.00		Gravel & clay	Dark Gray	· Gravel > clay · Maximum Gravel size 20mm
	7.00	1.60	v v v v v v v v	Weathered Basalt	Dark Gray	· Many Vesicular · Many Cracks · Maximum Core Length 15cm

CORE RECOVERY %	CORE RECOVERY cm	STANDARD PENETRATION TEST: DEPTH (m)	NUMBER OF BLOWS N (N)
	95	1.00	6/30
		1.30	
	100	2.00	7/30
		2.30	
	100	3.00	12/40
		3.30	
	100	4.00	12/30
		4.30	
	80	5.00	50<
	95	6.00	50<
	100	7.00	50<

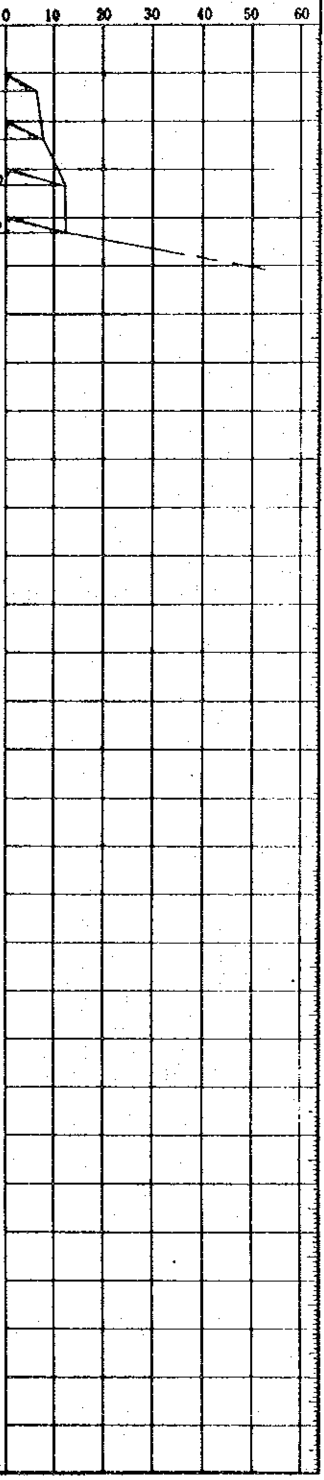


Fig. IV-31 **GEOLOGICAL RECORD OF BORING** HOLE No. B - 25

PROJECT	B.B. — P.L. — L.R.C.P	LOCATION	G.R.N.W. ~~Br.~~ Pit (STA 61+48)		
GROUND ELEVATION	8.56 M	DEPTH OF HOLE	12.0 M	ANGLE FROM VERTICAL	42°
DIAMETER OF HOLE	76.2 mm	MACHINE	A ∝ C	DATE OF DRILLING	9.3.79 — 17.3.79
CORE RECOVERY	49.6 %	DEPTH TO GROUND WATER LEVEL IN HOLE	5.0 M		
		DRILLED BY	R. Gtlurbunun ∝ R. Gothool	LOGGED BY	K. Narita

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	FIELD OBSERVATION COLUMN SECTION	SOIL OR ROCK CLASSIFICATION	COLOUR	DESCRIPTION	CORE RECOVERY %	cm	STANDARD PENETRATION TEST DEPTH (m)	NUMBER OF BLOWS N (N) 0 10 20 30 40 50 60
8.26	0.40	0.40		Block	Gray	· Block of Basalt		90		
						· Porous		80		
						· Maximum Core Length 25 cm		80		
						· Maximum Aggregate size 15 cm		85		
						· Aggregate : Coral Sand and Crushed Basalt		20		
				Concrete	Dark Gray ∝ White			40		
								30		
								40		
1.76	9.15	8.75						30		
				Gravel ∝ Sand	Dark Gray	· Gravel > Sand · Maximum Gravel size 40 mm · Very Compacted		80		
								60		
-0.26	12.00	2.85						50		

V. ROAD AND INTERCHANGE

CONTENTS

V. ROAD AND INTERCHANGE

A. Outline

5.01 In this section we describe the design standard and design manual for detailed design of the road and the intersections. Road design standards are fixed after the discussion with the engineers of M.O.W. and study of ROADS IN URBAN AREAS, LAYOUT OF ROADS IN RURAL AREAS published by H.M.S.O. which is used in Mauritius, refering to A POLICY OF GEOMETRIC DESIGN OF RURAL HIGHWAYS and ROAD ORDINANCE OF JAPANESE GOVERNMENT.

B. Geometric Design Standards

1. Horizontal Alignment

a. Main Road

Design Speed	100 - 80 Km/H
Minimum Curve Radius	640 - 440 m
Maximum Superelevation	7 %

b. Access Road to Beau Bassin

Design Speed	60 Km/H
Minimum Curve Radius	150 m
Maximum Superelevation	7 %

c. Ramp of Interchanges

Design Speed	40 Km/H
Minimum Curve Radius	30 m
Desirable Maximum Superelevation	7 %
Maximum Superelevation	10 %

d. Roundabout

Design Speed	25 - 30 Km/H
Minimum Curve Radius	25 m
Crossfall	2.5 %

2. Vertical Alignment

a. Main Road

Minimum Gradient	0.3 %
Desirable Maximum Gradient	3.0 %
Maximum Gradient	5.0 %

b. Access Road and Others

Minimum Gradient	0.3 %
Desirable Maximum Gradient	5.0 %

c. Ramp

Minimum Gradient	0.3 %
Desirable Maximum Gradient	4.0 %
Maximum Gradient	8.0 %

d. Roundabout

Minimum Gradient	0.3 %
Desirable Maximum Gradient	4.0 %
Maximum Gradient	5.0 %

e. Other Roads

Minimum Gradient	0.3 %
Desirable Maximum Gradient	5.0 %
Maximum Gradient Upward	10.0 %
Maximum Gradient Downward	12.0 %

3. Sight Distance

See Table V-1.

4. Width of Lane

a. Main Road	3.6 m
b. Access Road	3.6 m
c. Ramp and Round	See Table V-3
d. Climbing Lane	3.0 m

5. Width of Median

a. Main Road

Desirable Width	4.5 m
Minimum Width (on bridges)	1.5 m

b. Other Roads

Desirable Width	1.5 m
Minimum Width	1.0 m

6. Width of Shoulder

	Left side	Right side
a. Main Road		
Embankment and Cut Section	2.0 m	-
Bridges Section	1.2 m	0.5 m
b. Ramp	2.0 m	0.5 m
c. Roundabout	0.5 m	0.5 m

7. Right of Way

a. Main Road	15.0 m from the edge of carriageway. 2.0 m from the edge of structure.

8. Crossfall

a. Carriageway	2.5 %
b. Shoulders	4.0 %

9. Ramp Terminals

a. Entrance Terminal

Entrance Taper	40 : 1

b. Exit Terminal

Exit Taper	25 : 1

10. Clearances

a. Main Road

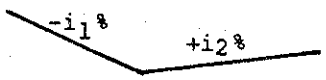
Vertical Clearance	5.1 m
Clearance from the left edge of traffic lane to the structure	2.0 m
Clearance from the right edge of traffic lane to the structure	0.75 m

b. Other Roads

Vertical Clearance	5.1 m
Clearance from the edge of traffic lane to the structure	1.2 m

Table V-1 Sight Distance

Design Speed	Minimum Stopping Sight Distance	Minimum Overtaking Sight Distance	Minimum Desirable Radius	Absolute Minimum Radius with Maximum Superelevation	Minimum Radius for Curves without Transitions	Stopping Sight Distances K values for Crests	Stopping Sight Distances K values for Sags	Overtaking Sight Distances K values for Crests on Single Carriage ways
km/hr	m	m	m	m	m	m	m	m
100	200	420	640	330	1,370	45	45	210
80	130	360	440	230	1,220	20	30	150
60	90	290	270	150	600	10	15	90



Sight Distance = $\{(-i_1) + (+i_2)\} \times K$

Table V-2 Speedchange Lane

Design Speed km/h	Visibility Distance at Junction m	Acceleration Lane Length including nose m	Deceleration Lane Length including nose m	Right turn Deceleration Lane Length including taper m
100	210	270	150	150
80	180	210	135	135
60	150	150	120	120

Table V-3 Width of Lane

Inner Radius m	Design Speed m	Single Lane Width m	Single Lane Width with space to pass stationary vehicle m	Two Lane Width for one or two way traffic m
10.7	19	5.5	10.2	11.4
15.2	24	5.2	9.3	10.5
22.9	29	4.9	8.4	9.6
30.5	32	4.6	7.8	9.0
38.1	35	4.3	7.5	8.7
45.7	40	4.3	7.2	8.4
60.0	45	4.3	6.9	8.1
90.0	56	4.3	6.9	8.1
120.0	61	4.3	6.6	7.8
150.0	64	4.3	6.3	7.5
∞		4.3	6.1	7.2

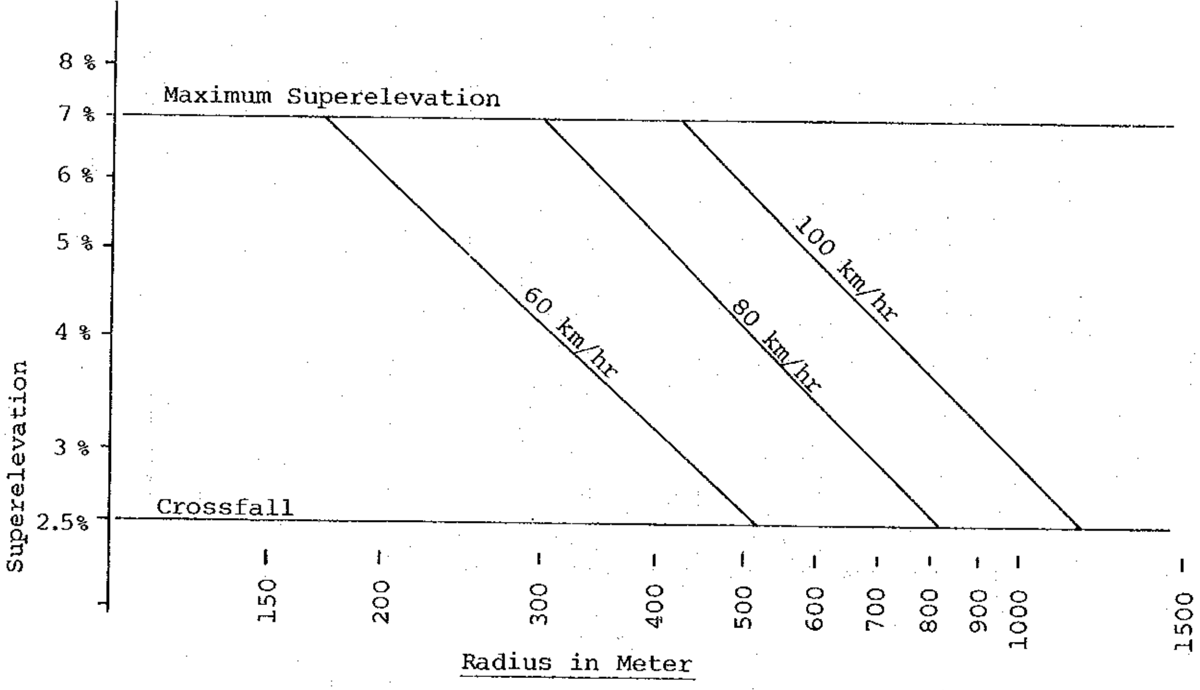
Fig. V-1 Superelevation

Minimum Radius

60 km/hr	1100 m
80 km/hr	2000 m
100 km/hr	3100 m

$$Re = \frac{V^2}{127(i+f)} \qquad i = -0.025 \quad f = 0.05$$

i : cross fall
f : side friction factor



C. Alignment

5.02 The alignment which was selected in the course of the Feasibility Study has been the base, while consideration has been paid to the undermentioned:

1. Horizontal Alignment

a. To avoid impeachment upon the existing irrigation facilities (such as reservoirs, canals, etc.) as the projected road runs through the sugarcane fields;

b. To avoid the dwelling area as far as possible;

c. To avoid the spoilage of the facilities for public service;

d. To adhere to the alignment which will do without excessive cutting/embankment works;

e. To avoid such an alignment which may result at additional gradient to the profile;

f. The radius of the main track is to be made R = 500m as the minimum (which is equivalent to the radius of the disused railway), by avoiding smaller radius;

g. Clothoid curve which is supposed to be so far the best will be adopted as a transition curve.

2. Vertical Alignment

a. That which will be properly balanced with the horizontal alignment has been adopted;

b. To avoid excessive cutting/embankment works or to keep balance between the cutting and embankment as far as possible;

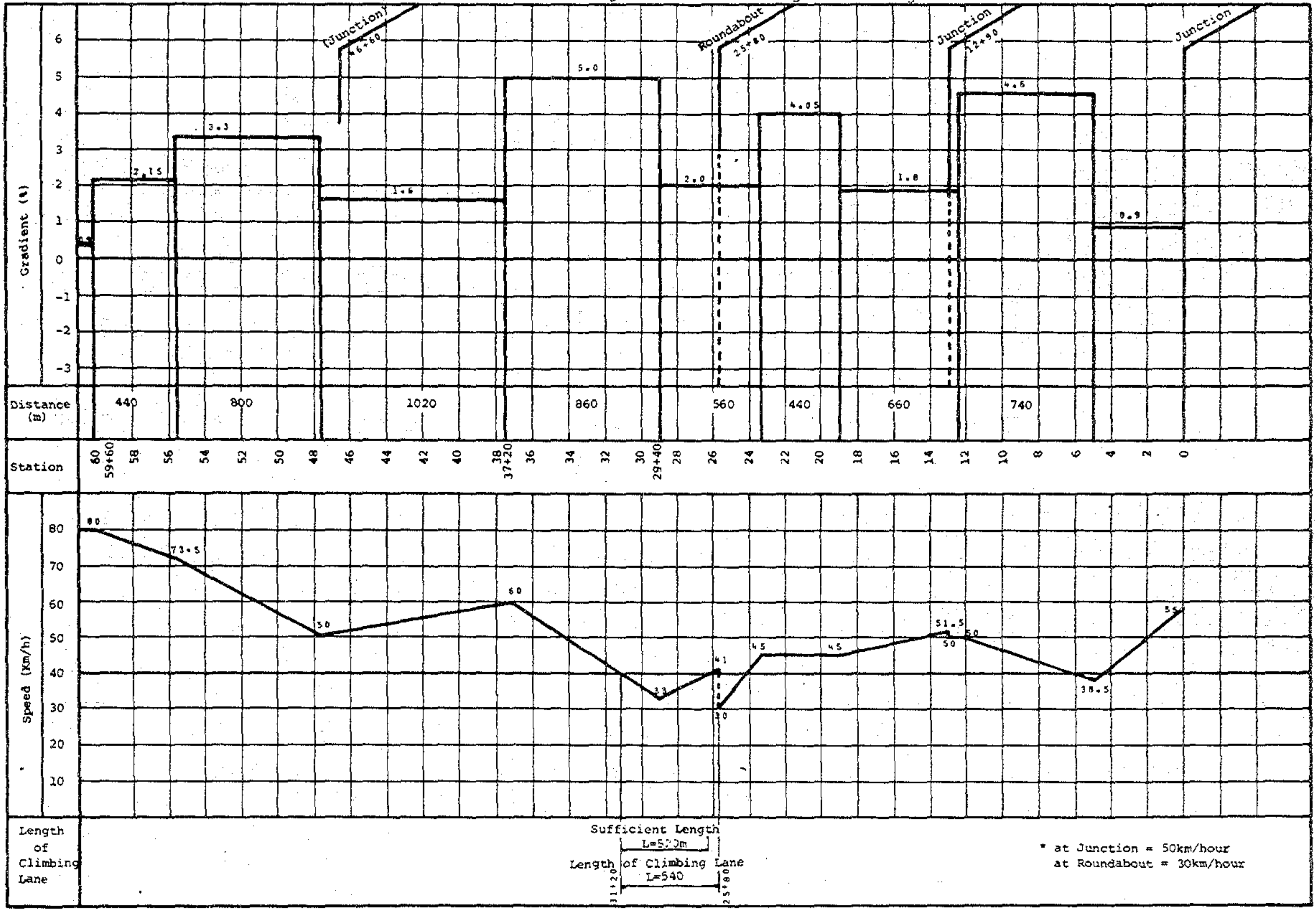
c. Although the present topography has an average gradient of 4%, it goes beyond 10% at places resulting at 10% or more gradient if the road's profile is simply to be governed by the topography. By taking into consideration the convenience of heavy vehicles like trucks and busses, the vertical alignment has been kept at 5% as far as possible;

d. Siphons and/or inverted siphons have been introduced to avoid the canals cutting across the main track.

3. Climbing Lane

5.03 When the heavy vehicles run uphill along the road with a shape gradient, their running speed would drop to deter advancement of the following vehicles. Climbing Lane has, therefore, been proposed where the distance which needs driving at decreased speed of 40 Km/h (less than half of the regular running speed) extends to 500m (ref. Fig. V-2).

Fig. V-2 Estimated Figure for Climbing Lane Length



* at Junction = 50km/hour
at Roundabout = 30km/hour

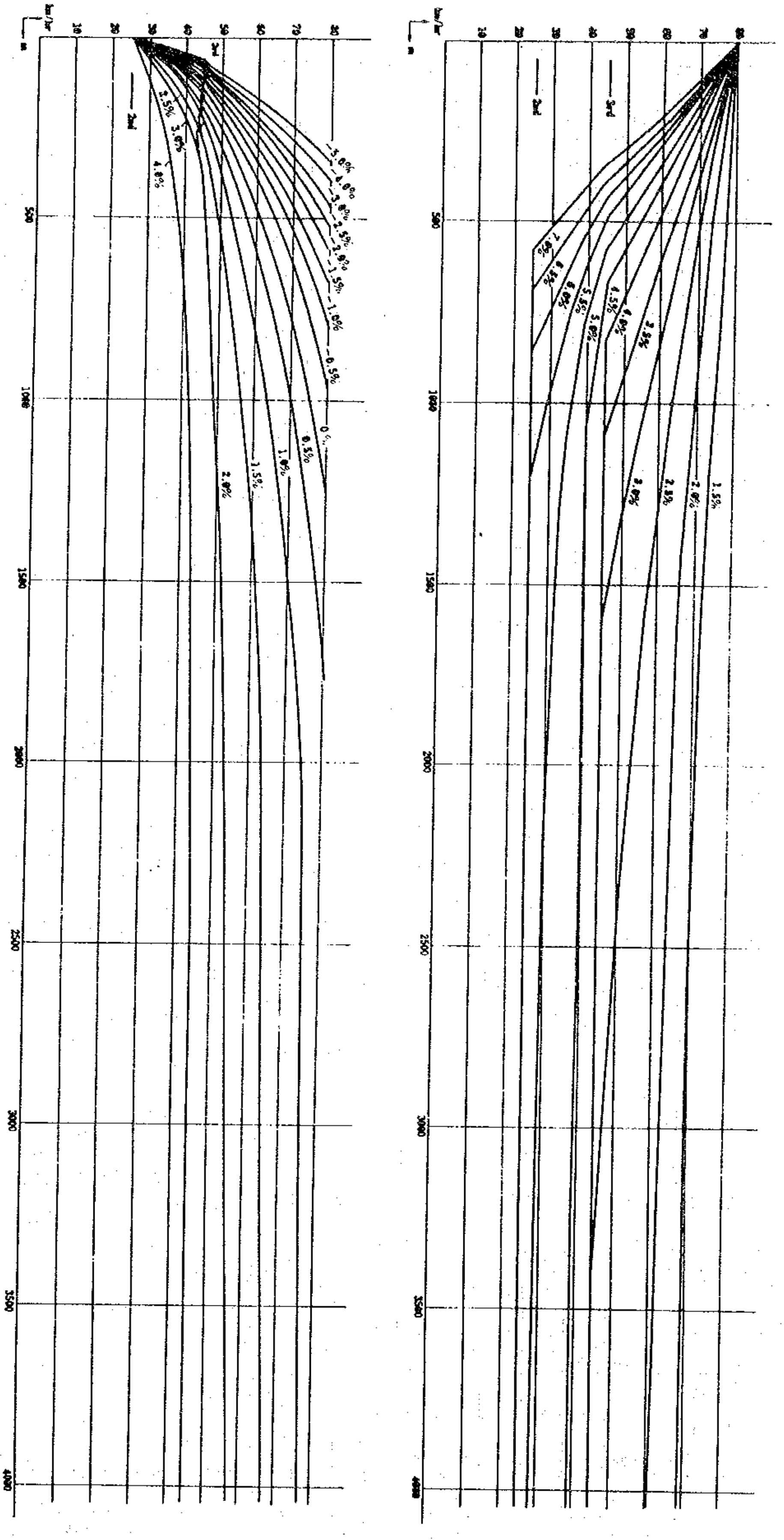


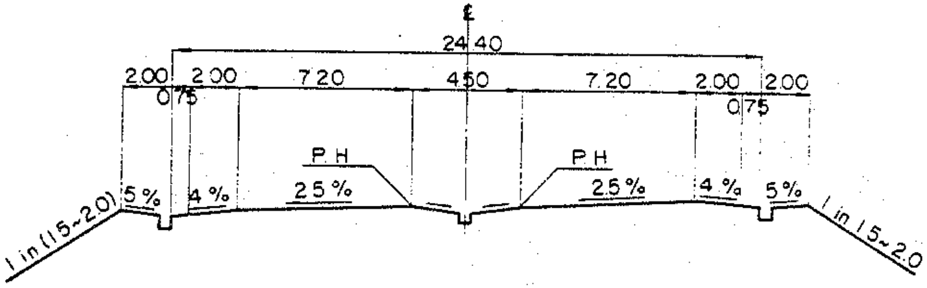
Fig. V-3 Speed Distance Curves of a Typical Heavy Vehicle on Various Grades

D. Typical Cross Section

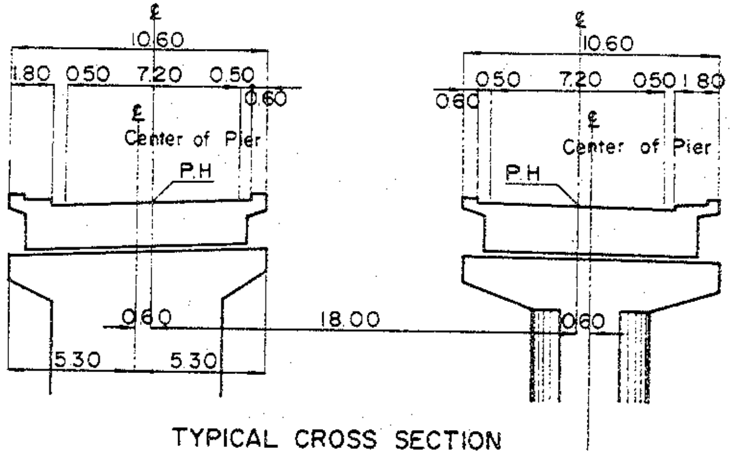
TYPICAL CROSS SECTIONS

Unit meter

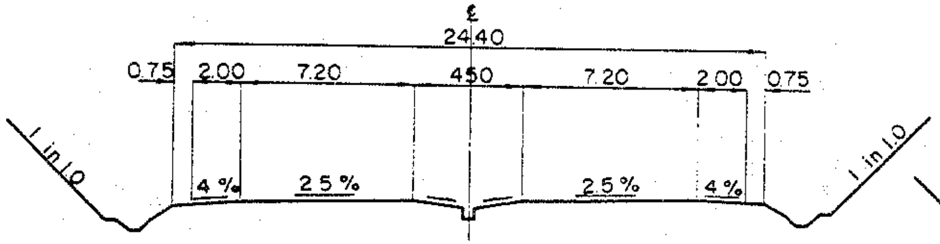
EMBANKMENT



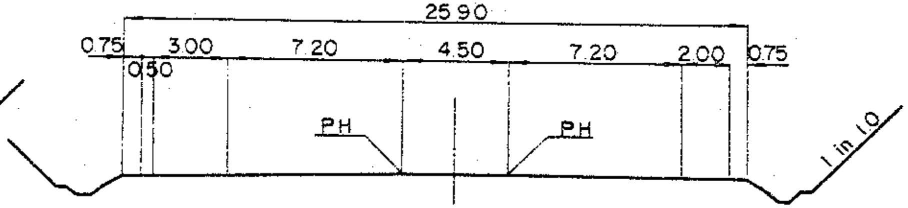
G.R.N.W & S.T RIVER SECTION



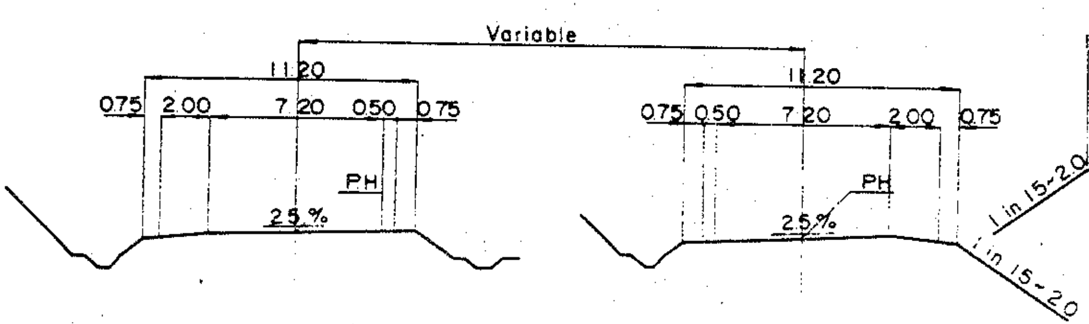
CUT



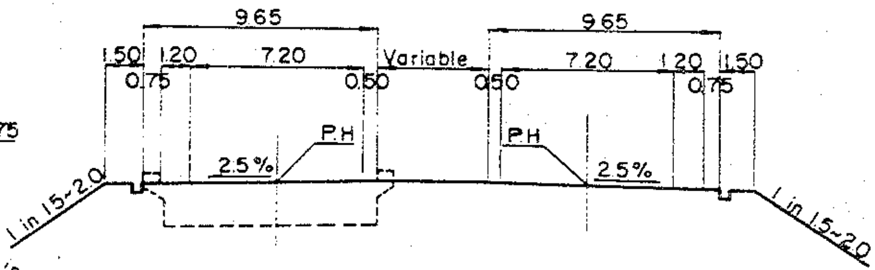
TYPICAL CROSS SECTION WITH CLIMBING LANE



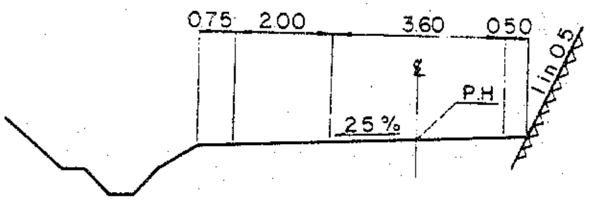
SEPARATE SECTION

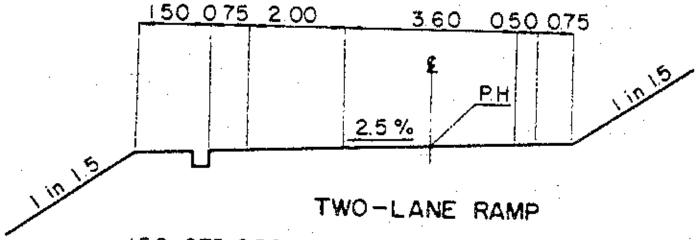


CROSS SECTION OF RING ROAD

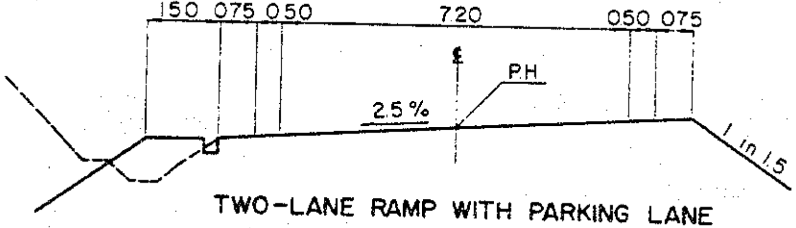


SINGLE LANE RAMP

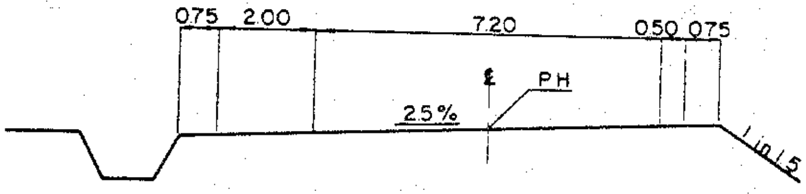




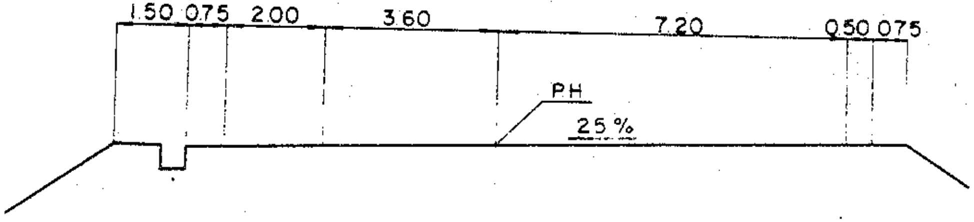
TWO-LANE RAMP



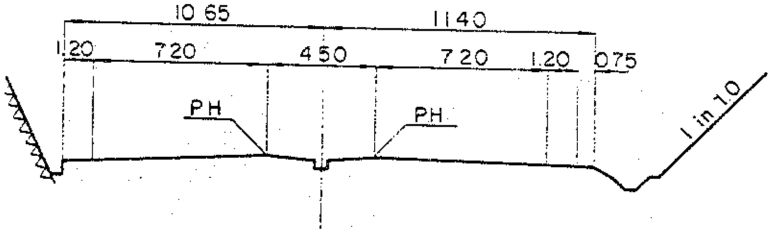
TWO-LANE RAMP WITH PARKING LANE



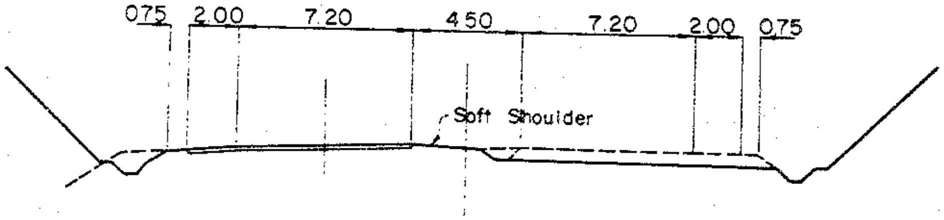
WEAVING SECTION WITH PARKING LANE



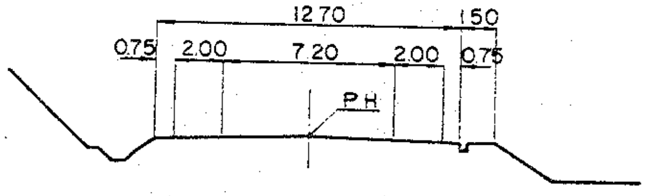
M1,M2 ROAD (UNDER SECTION)



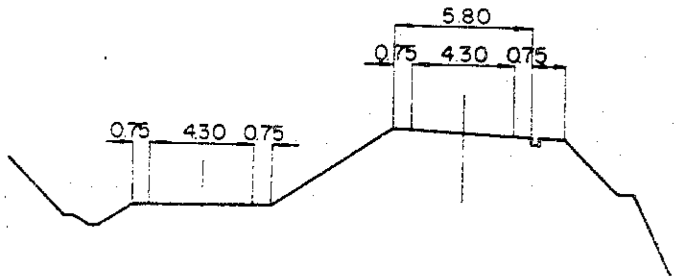
MAIN ROAD (BARKLY ~ St. MARTIN)



ACCESS ROAD TO BEAU BASSIN

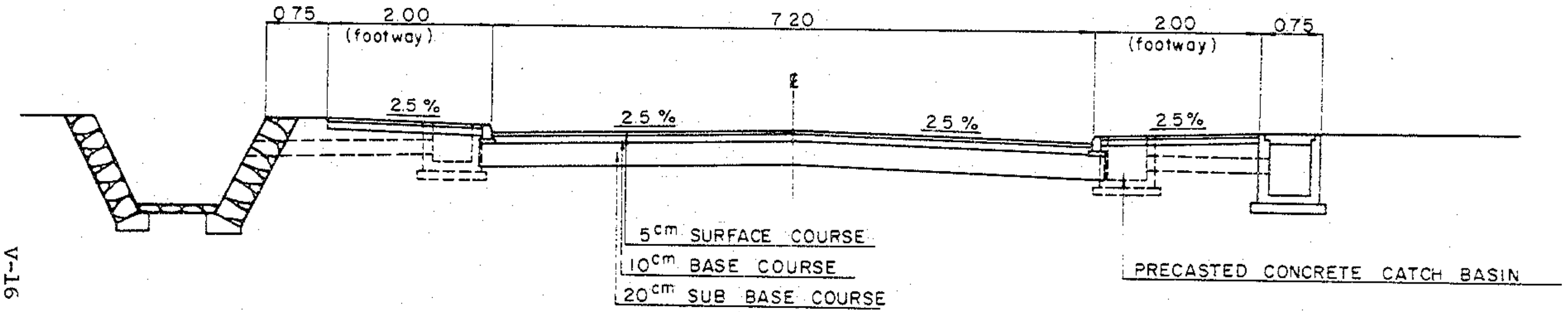


ENTRANCE ROAD TO MOKA ROAD

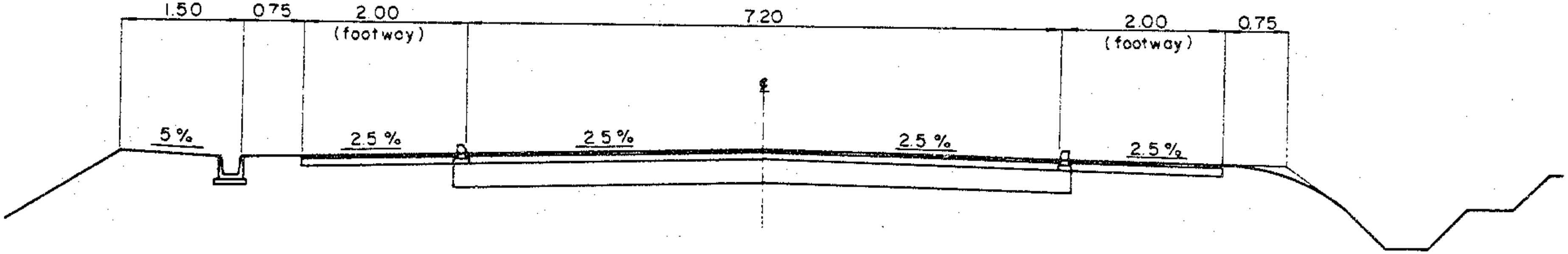


ACCESS ROAD TO BEAU BASSIN

TYPICAL CROSS SECTION TYPE-A



TYPICAL CROSS SECTION TYPE-B



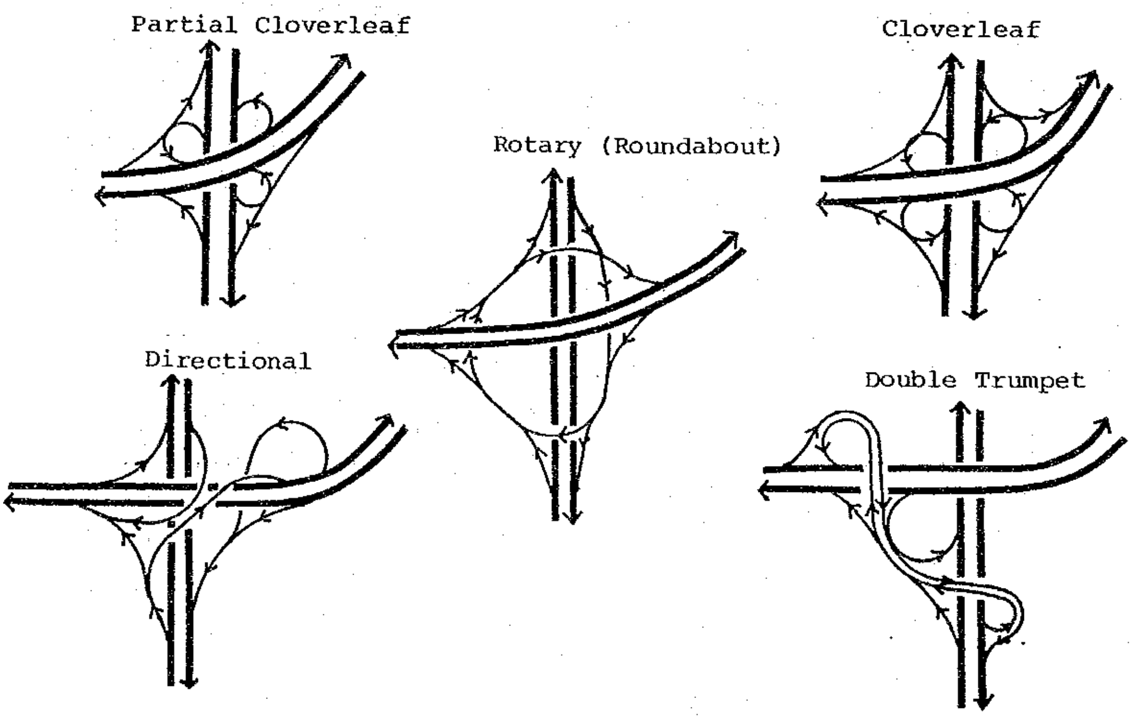
E. Design of Junctions

5.04 Design of junctions has been made by taking into consideration the development plan in Point aux Sables District as well as the increase in traffic volume after completion of Port Louis Ring Road which has been reflected on the previous estimate of the traffic volume at each junction. The following are some of the basic concepts adopted in design of junctions:

1. Motorway Junction

5.05 The future total entrance traffic volume at the Motorway junction has been estimated at 139,000 p.c.u./12 hrs. in 2002. The most appropriate type of Motorway junction would be deemed grade-separated; the following different types of junction have been examined.

Fig. V-4 Different Types of Junction



Partial Cloverleaf

Rotary (Roundabout)

Cloverleaf

Directional

Double Trumpet

Fig. V-4 COMPARATIVE STUDIES FOR TWO ALTERNATIVE PLANS

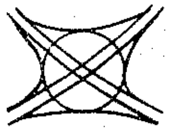
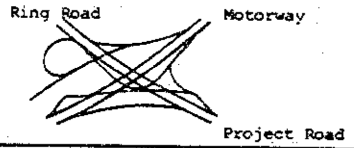
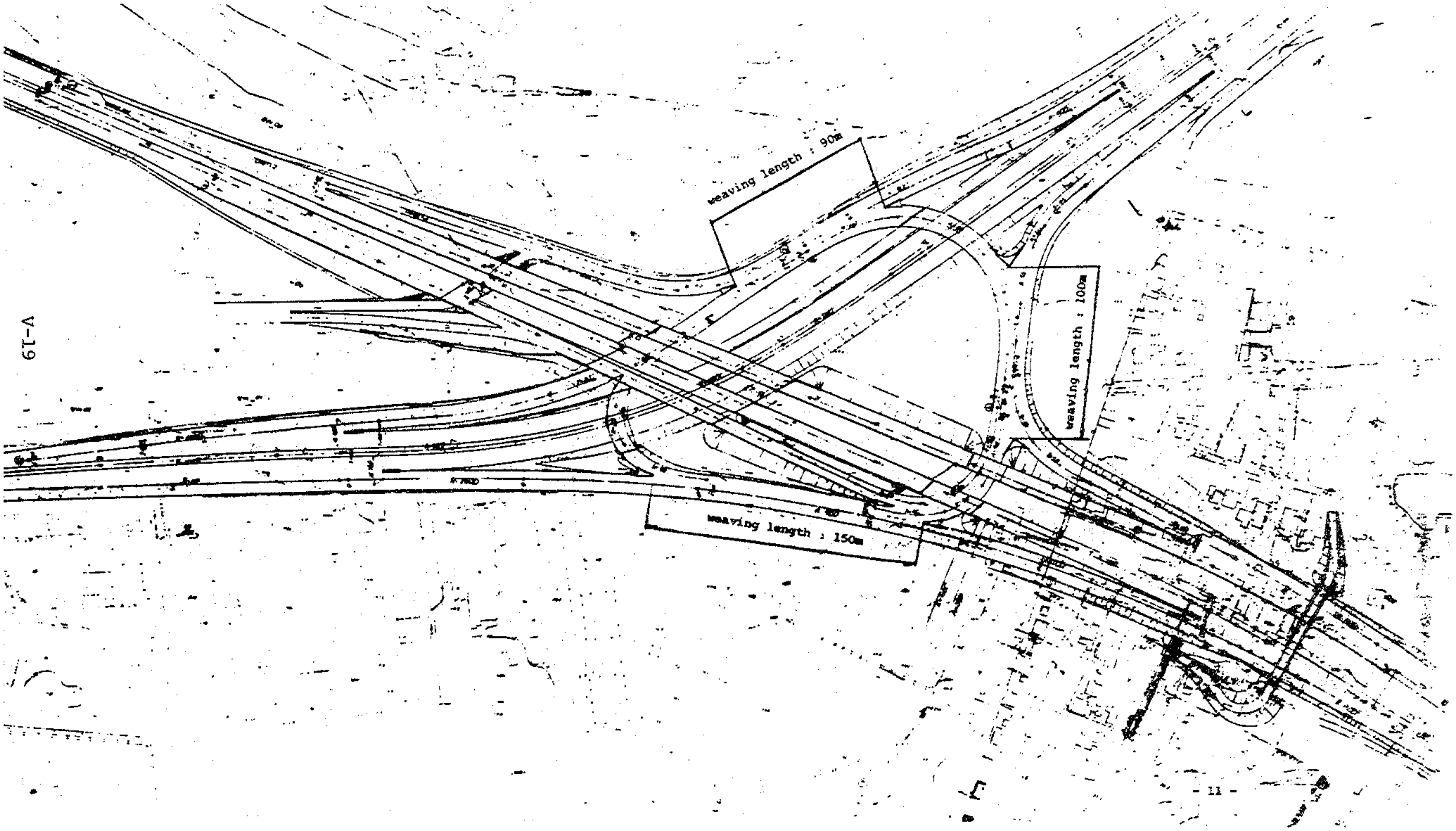
Alternative Plans	Plan A	Plan B
Type		
Alignment and Vehicle Running	There ia almost no danger of vehicle running, because conventional traffic services for roundabouts prevail in the country.	Traffic services are provided for all directions through ramps, but it would be deemed uneconomical for the project as a whole to make only the Motorway junction highly standardized.
Type and Construction of Structures	The construction of three bridges (with a simple design) and two box culverts will enable to be staged in correspondence to the construction period of the ring road.	The construction of four bridges (with a complicated design) will be unable to be staged; exante correspondence would be required before the construction of the ring road.
Drainage	There are no particular problems.	There are no particular problems.
Operation and Maintenance	There is no problem because of a simple bridge design.	There are some problems to be solved for expansion joints, painting, the superannuation of slabs and so on, because the superstructure of the bridges is of a complicated metal type.
Land-Use	As a loop is constructed on a ground line, there will be no problems in entrance and exit traffic running and land acquisition.	As outer ramps are of a fly-over and embankment type, the land in and around the junction will be divided into sections.
Environment	Since the vertical gradient is gently sloping down, there will be almost no problem for noise and air pollution.	The plan B is inferior to the plan A because of the steep vertical gradient.
Construction Cost	The construction cost will be decreased because of the construction of a few structures.	The construction cost will be increased because of the construction of many structures with a complicated design.
Coordination with Future Development Plans	It is easy to be coordinated.	It is difficult to be coordinated.
Connection with the Existing Peripheral Roads	Traffic will smoothly run because of the balanced design standards of the junction with the other peripheral roads.	A smooth traffic flow cannot be expected because of a high standardization of the junction.
Acreage of the Site	Small	Large
Comprehensive Evaluation	By taking into consideration harmonization with the existing peripheral roads & regional characteristics, the execution of a staged construction and the construction cost, it follows that the plan A is fairly favourable.	There is no problem in traffic capacities, but some problems will stem from harmonization with regional characteristics, a change in the initial investment induced by the execution of a staged construction and a connection period of the ring road.

Fig. V-5 Motorway Junction



5.06 Among the multifarious types of junctions, roundabout types have been selected for the Motorway junction on the following conditions:

(1) The type of the Motorway junction is restricted by topographical conditions and the present land-use; and

(2) Since the construction period of the ring road differs from that of project road and it is easy for the Motorway junction to take a staged construction, the Motorway junction must be designed so that is will be able to cope with the case in which the alignment of the ring road is changed and to decrease the initial investment.

5.07 As a result of detailed technical study for the selected two types, the motorway junction has been designed as a roundabout type (see Table V-4). In addition, the selected roundabout type of the Motorway junction will be able to cope with any situation without having a problem about the excess investment because of the staged construction taken for the Motorway junction.

5.08 As a result of technical studies on traffic capacities and design standards, the number of lanes and the length of a weaving section for the Motorway junction have been determined as shown in Fig. V-5.

2. S. Hill Junction

5.09 According to the report prepared by JICA, the S. Hill junction was so designed as to construct ramps for traffic in both directions of Beau Bassin and Port Louis, linking the project road and the A_1 road. However, as it has been found topographically difficult to construct the ramps and the new construction of the Coromandel junction allows accessibility towards Beau Bassin and Port Louis, the junction has been so re-designed as to construct only one ramp for traffic towards Beau Bassin from Port Louis.

3. Coromandel Junction

5.10 The Coromandel junction will hold not only the traffic volume associated with the Pointe aux Sables Development Plan, but also that associated with the existing Coromandel industrial estate. The junction, furthermore, contributes to make more effective the intensity of an industrial complex under two development plans by linking both the Pointe aux Sables and the Coromandel districts through the Coromandel junction.

5.11 As a result of technical studies, a type of the Coromandel junction has been determined to be of a grade-separated roundabout.

5.12 As a result of technical studies on traffic capacities and the design standards, the number of lanes and the length of a weaving section at the junction have been determined as shown in Fig. V-6.

4. Richelieu Junction

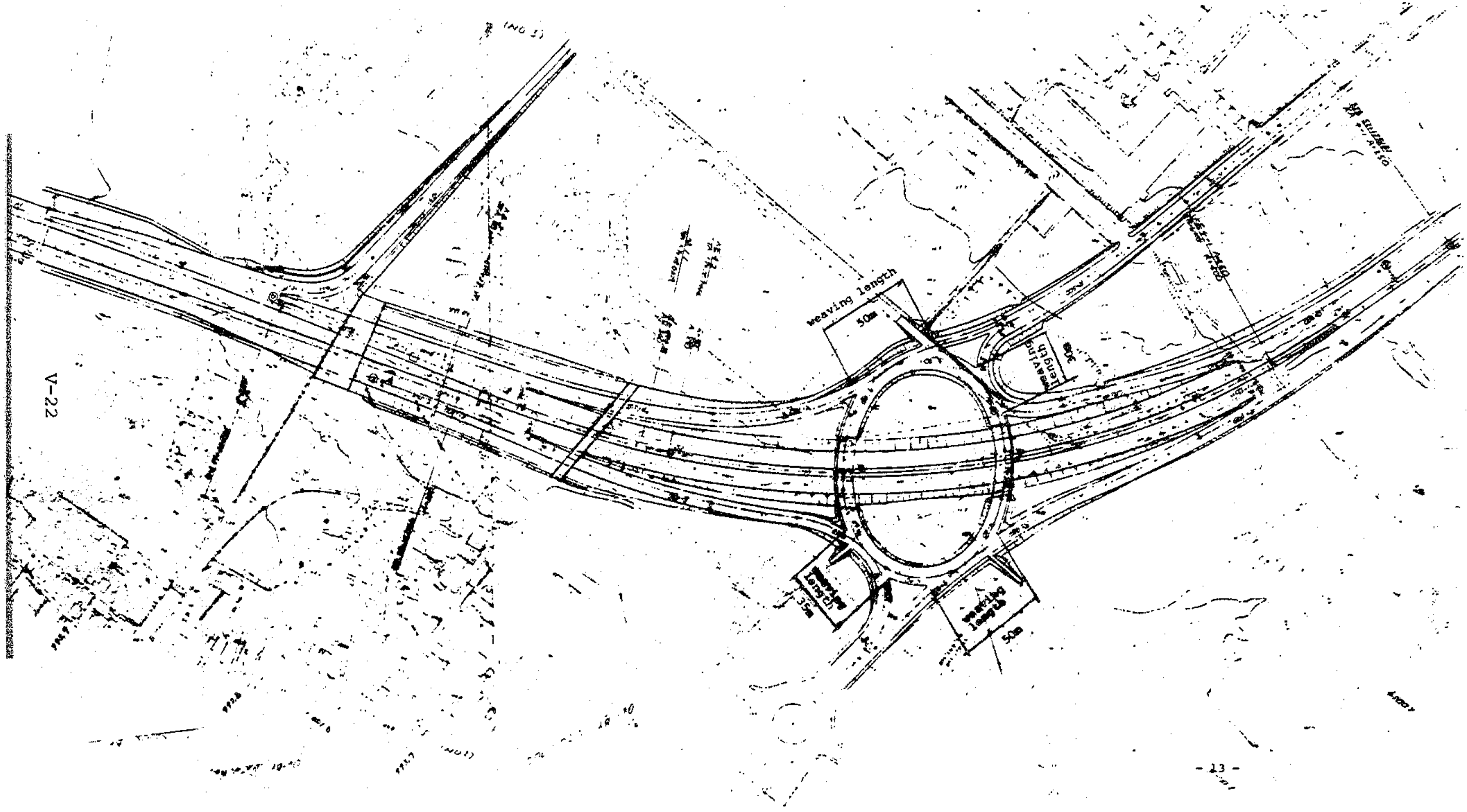
5.13 It is judged that the future traffic volume at the Richelieu junction will be fairly reduced after completion of the Coromandel junction.

5.14 Accordingly, the junction is designed as an at-grade type with the broad median for the cross traffic keeping safety from the through traffic.

5. Chebel Branch Road Junction

5.15 According to the report prepared by JICA, the Chebel branch road junction was designed as a roundabout type. However, it is obvious from the re-estimation of the future traffic volume that the junction will be capable of meeting the future traffic demand in 1992, but not in 2002*.

Fig. V-6 Coromandel Interchange



5.16 The following two measures to meet the future traffic demand are considered essential.

(1) The Chebel branch road junction is designed as a grade-separated type as to be capable of meeting the future traffic demand in 2002 even at the time of opening to traffic in 1982; and

(2) The junction is designed as a roundabout type, which will be capable of coping with the future traffic requirement in 1992, at the first stage, while re-designed as a grade separated type, which will be capable of coping with the future traffic requirement in 2002, at the second stage.

5.17 Case (2) would be deemed the most appropriate, because Case (1) necessitates a great amount of the initial investment and its utility maximization will be achieved 20 years after the opening to traffic. However, even in case (2), the junction will be designed as a grade-separated roundabout type.

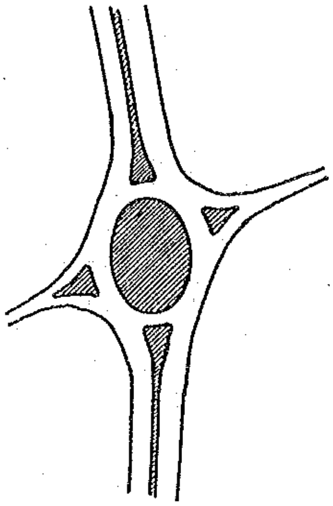
5.18 For as a grade separation, comparative studies for the following two alternatives have been made.

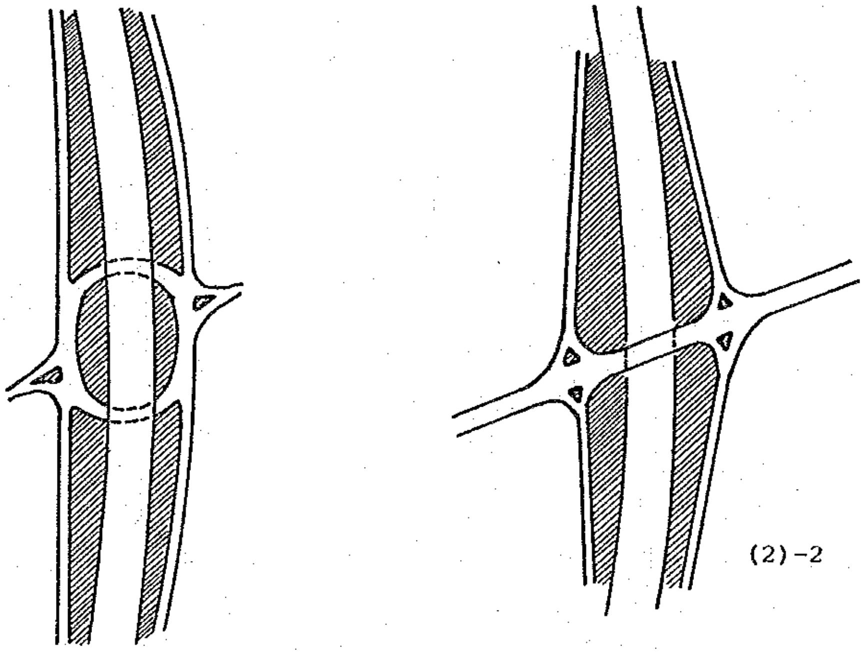
(2)-1 As the traffic volume on a through way of the project road comes up to the maximum level, it is proposed to pass the project road over the Chebel branch road; and

(2)-2 As the increased traffic flow, which cuts the project road from the Chebel branch road and merges the project road towards Port Louis, will reduce the capacity of the Chebel branch road junction, it is proposed to pass the Chebel branch road over the project road.

5.19 From the standpoints of the investment effect of the above-mentioned two cases and the safety of vehicle operation, (2)-2 would be deemed the most appropriate type for the Chebel branch road junction.

Fig. V-7





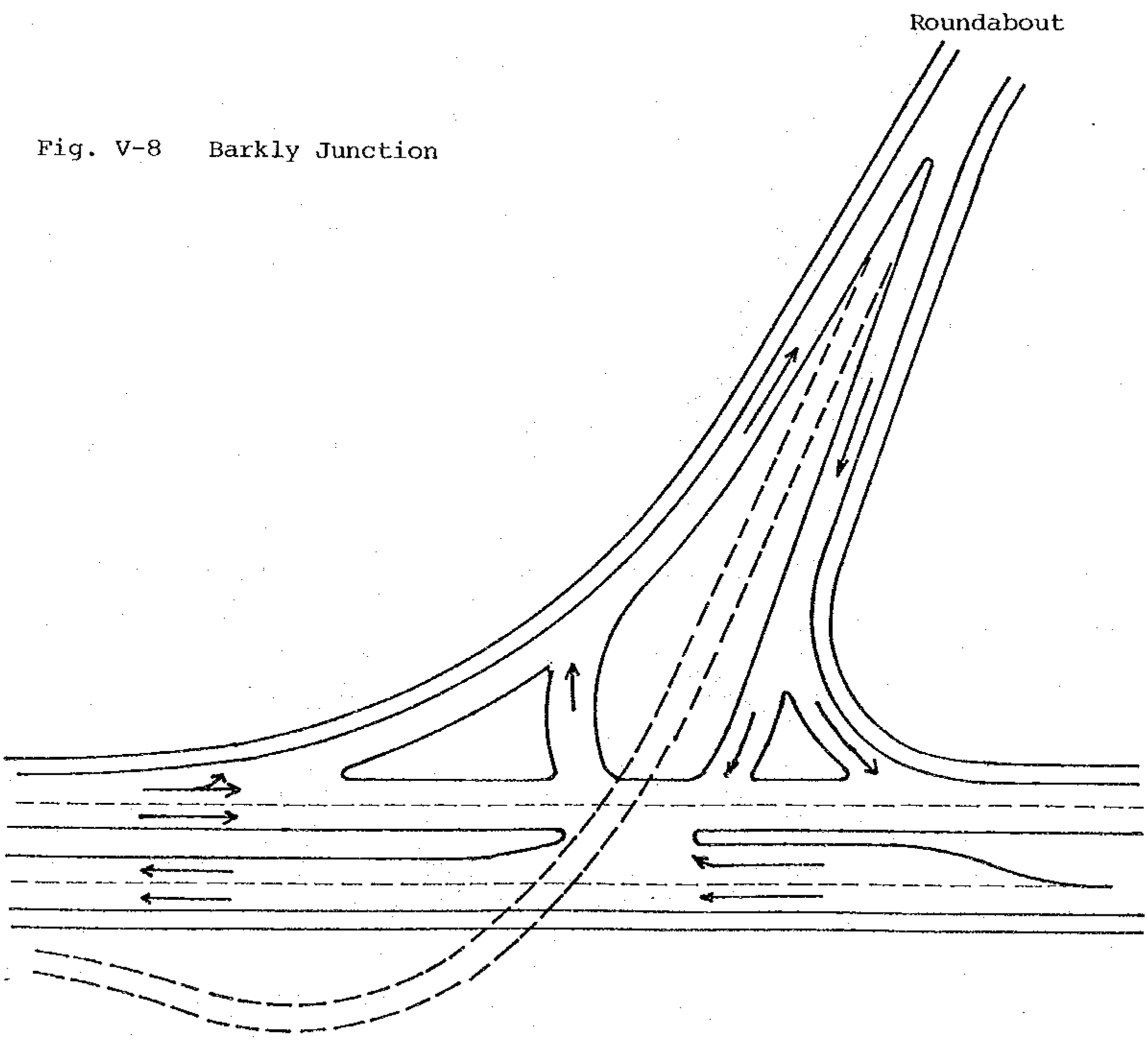
(2)-1

(2)-2

6. Barkly Junction

5.20 According to the report prepared by JICA, the type of the Barkly junction was of a channelized at-grade intersection; however, as a result of the estimation of the future traffic volume in consideration with the Pointe aux Sables Development Plan, the junction is capable of meeting the future traffic demand in 1992, but not in 2002, because the traffic, which runs from Beau Bassin to Port Louis, crosses a through way of the project road. Even if the junction is designed as a roundabout type, it will be incapable of meeting the future traffic demand in 2002. It is, therefore, necessary to design the junction as a grade-separated type.

Fig. V-8 Barkly Junction



7. Beau Bassin Roundabout

5.21 The future traffic volume at the Beau Bassin roundabout has been forecast as follows:

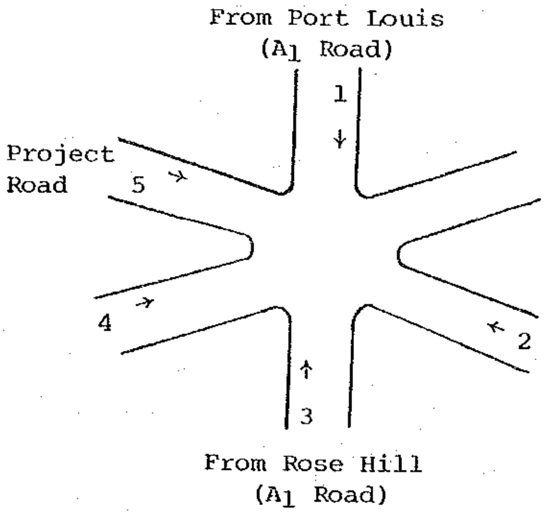
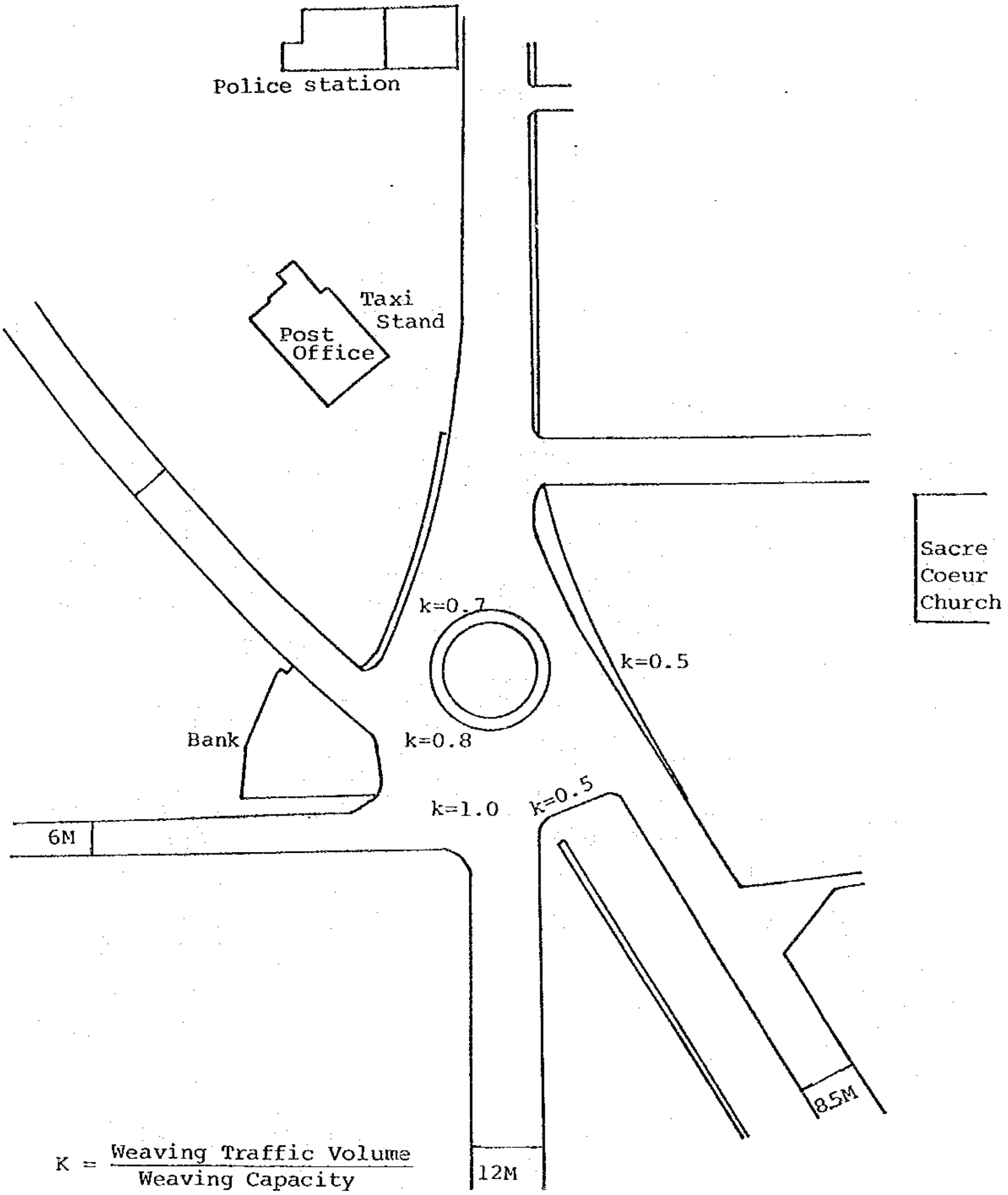


Table V-5 Future Traffic Volume during the Morning Peak Hours (P.C.U./hr)

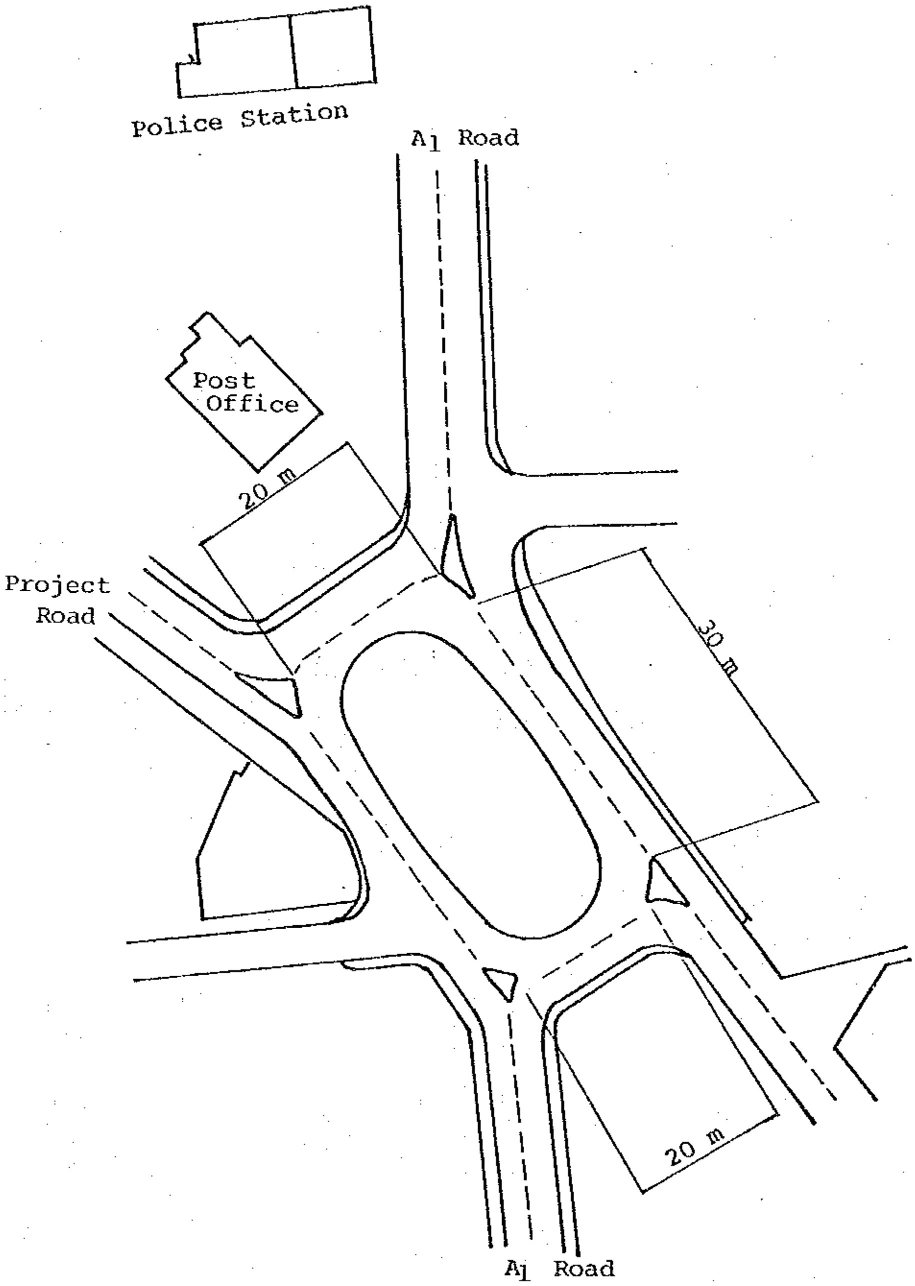
Direction	Year 1992	 2002
1	800	900
2	500	700
3	700	1,100
4	-	-
5	100	300
Total	2,100	3,000

Fig. V-9 Beau Bassin Roundabout
Present Situation



$$K = \frac{\text{Weaving Traffic Volume}}{\text{Weaving Capacity}}$$

Fig. V-10 An Improvement Plan of the Beau Bassin Roundabout



5.22 Generally speaking, as the traffic capacity of a 5-way conventional roundabout has been estimated to be less than 3,000 + α p.c.u./hr., the Beau Bassin roundabout will be capable of meeting the future traffic demand in 2002. As a result of technical studies on the traffic capacity of the weaving section, the shape of the Beau Bassin roundabout is different from that mentioned in the report prepared by JICA as shown in Fig. V-10.

F. Drainage

5.23 Prior to the drainage design, collecting the past rainfall data in Mauritius the formula of rainfall intensity for the short-term was formed. After that the catchment areas were set up and the amount of rainfall entering the inlet of the drainage structure undercrossing the main road was calculated and structures were designed.

5.24 The structures were designed as possibly using reinforced concrete pipes and using reinforced concrete box culverts at the sites where is need large cross-sectional area. (Refer to the attached Fig. V-12 and Table V-13.)

5.25 Catch pits were designed at joints where the side ditches meet the irrigation channel to prevent trash flowing into it.

5.26 Rainfall on the surface of the road shall be drained by side-ditches of the median strip, the shoulder and the toe of the slope.

5.27 It is hard to drain the surface water by the U shaped side ditches at the center of the median strip often for some years because the turf of the median strip will swell up.

5.28 Therefore, the side ditch of the median strip shall be set at the edge of the median strip adjacent to the lane. The shape of the ditch is a thin arc from the view point of traffic safety (refer to the contract drawings). Recently, ditches of this type have been adopted for the expressways in Japan, and we have obtained satisfactory results in respect to drainage and safety.

1. Formula of Rainfall Intensity for the Short Term

a. Data of Rainfall

5.29 Hourly rainfall by Dr. Mononobe's formula using probable daily rainfall calculated with data of daily rainfall are shown as follows.

Table V-6 One hour rainfall

2 years	60 mm/hr
3 "	73 "
5 "	85 "
7 "	95 "
10 "	104 "
20 "	121 "
30 "	131 "
50 "	144 "
75 "	155 "
100 "	162 "

5.30 Maximum rainfall and rainfall intensity during 85 years at Pamplemouses Meteorogical Station and Vacoas Meteorogical Station are shown as follows.

Table V-7 Maximum rainfall

Duration(minutes)	Rainfall(mm)	Intensity(mm/hr)
35	61	104
60	82	82

Table V-8 Rainfall Record at Pamplemouses
on 14th November 1959

Duration (minutes)	Rainfall (mm)	Intensity (mm/hr)
15	25	100
30	45	92
60	75	75

Table V-9 Rainfall Record at Vacoas
on 4th March 1951

Duration (minutes)	Rainfall (mm)	Intensity (mm/hr)
15	25	100
30	45	90
60	79	79

b. Formation of Rainfall Intensity for the Shor Term

5.31 Rainfall intensity shall be formed using special characteristic modulus method with above.

(1) Rainfall intensity:

$$I = \beta \cdot R$$

where

I : Rainfall intensity (mm/hr)

β : Characteristic modulus

R : Rainfall (mm)

(2) Characteristic modulus (β):
There are three basic formulas of characteristic modulus as follows.

Talbot's formula : $\beta = \dfrac{a'}{t + b}$

Sharman's formula : $\beta = \dfrac{a'}{tn}$

Kuno, Ishiguro's formula : $\beta = \dfrac{a'}{\sqrt{t} \pm b}$

5.32 Each modulus (a', b, n) shall be obtained under the conditions; $\beta = 1.0$ when $t = 60$ minutes.

In the case of Tarbot's formula

$$a' = b + 60$$

$$b = \frac{60 - \beta^t \cdot t}{\beta^t - 1}$$

where

β^t is the rate of rainfall intensity during t minutes against rainfall intensity during 60 minutes of same probable year.

$t = 15$ minutes

$$\beta^t = \frac{105}{80} = 1.3125$$

$b = 129$

$a' = 189$

as a result,

$$I = \frac{189}{t + 129} \times 80 = \frac{15120}{t + 129}$$

In the case of Sharman's formula

$$\log a' = \frac{\log \beta^t \cdot \log 60}{\log 60 - \log t}$$

$$n = \frac{\log a'}{\log 60}$$

$$\beta t = 1.3125$$

$$t = 15$$

$$\log a' = \frac{\log 1.3125 \times \log 60}{\log 60 - \log 15} = 0.3488$$

$$a' = 2.233$$

$$n = \frac{0.3488}{\log 60} = 0.2$$

as a result,

$$I = \frac{2.233}{t^{0.2}} \times 80$$

$$= \frac{179}{t^{0.2}}$$

In the case of Kuno & Ishiguro's formula

$$a' = \sqrt{60} \pm b$$

$$b = \frac{\sqrt{60} - \beta^t \sqrt{t}}{\beta t - 1}$$

$$\beta^t = 1.3125$$

$$t = 15$$

$$b = 8.5$$

$$a = 16.240$$

as a result,

$$I = \frac{16.246}{\sqrt{t} + 8.5} \times 80 = \frac{1300}{\sqrt{t} + 8.5}$$