6.4 Alternatives for KLE

6.4.1 Potential Alternatives

Part of the section along KLE has already been safeguarded for the expressway. As such, the location for the connection with PIE is more or less predetermined. Moreover, a suitable distance has to be kept away from the flyover of ECP. All these constraints have, by themselves, predetermined the location to be selected for a horizontal alignment.

For the longitudinal alignment, the connection with ECP, Nicoll Highway and PIE and the crossings with Geylang River, the National Stadium, Mountbatten Road and MRT, have to be taken into consideration. Among these, the National Stadium occupies a big piece of land, the way in which the new road is going to cross, determines the ways of the other sections. That is, if a flyover is used, it must extend all the way from ECP to PIE. (Flyover draft) On one hand, if the National Stadium is cut across by an underground tunnel, there are alternatives of having an above or below ground approach for the crossing between ECP and MRT. Over here, the alternative based on the horizontal alignment draft, which maximizes the usage of the land already safeguarded for the expressway, and 2 modified underground drafts which are best utilized, the horizontal alignment of the stretch under the section between ECP and the National Stadium are given as 3 horizontal alignment drafts in Fig. 6.13.

6.4.2 Necessary Number of Lanes

The future traffic volume in the year 2010 is shown in Fig. 6.14. Fig. 6.15 shows the number of lanes required. According to the figure the necessary number of lanes for KLE in each direction is 3 lanes.

6.4.3 Geometric Conditions

For all the potential alternatives established for KLE, the selection target from a geometric viewpoint is basically the longitudinal alignment. The result of a brief discussion on all the longitudinal alternatives is given in Fig. 6.12.

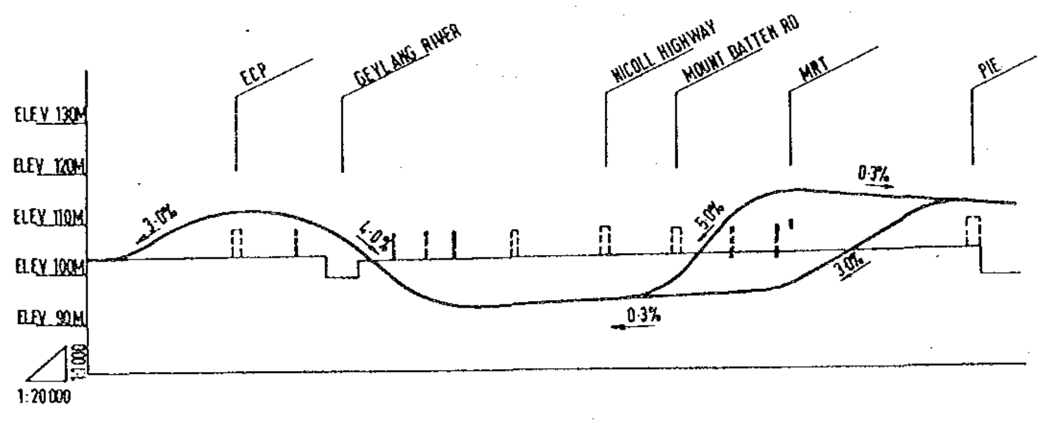
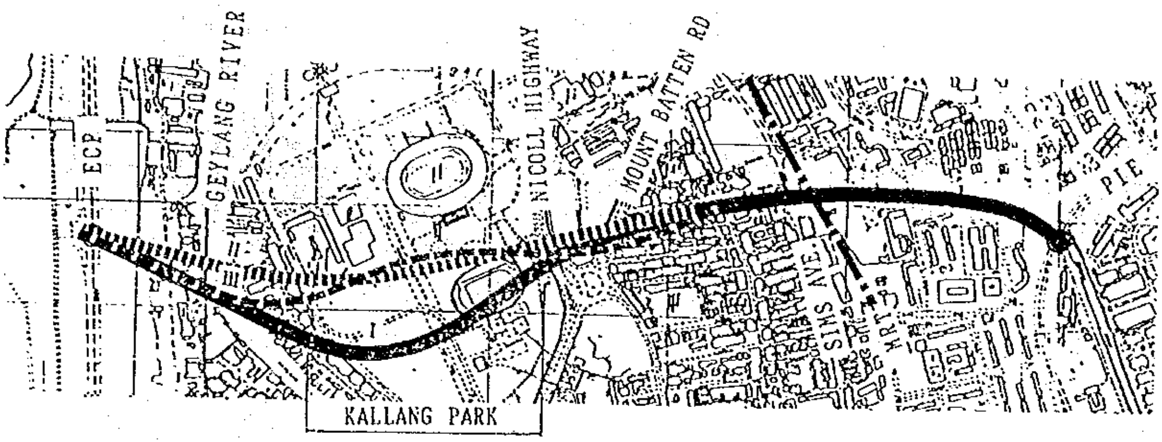


Fig. 6.12 Proposed Profile of KLE



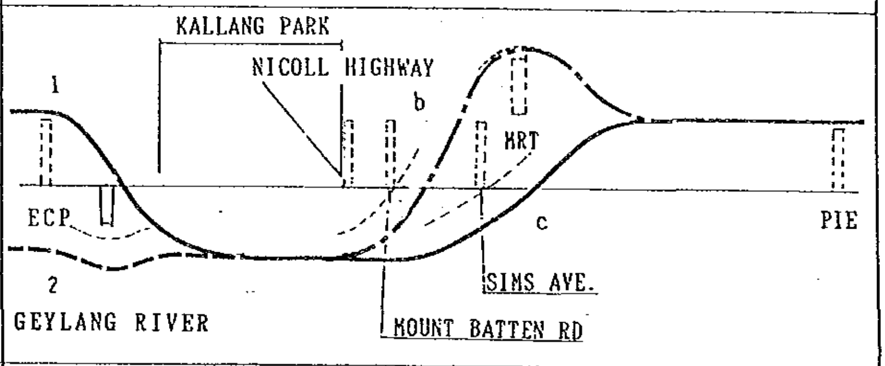
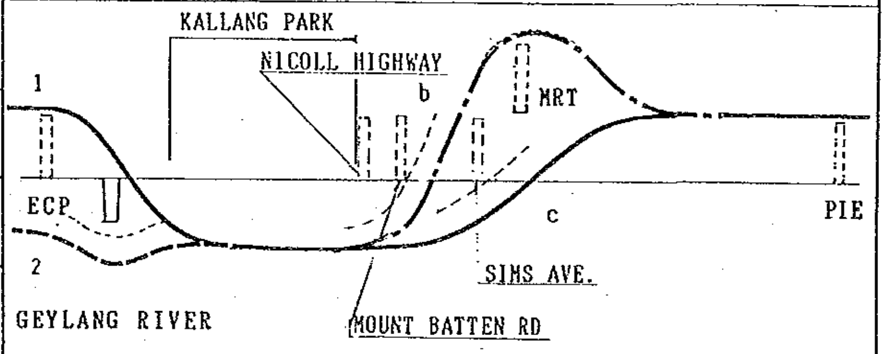
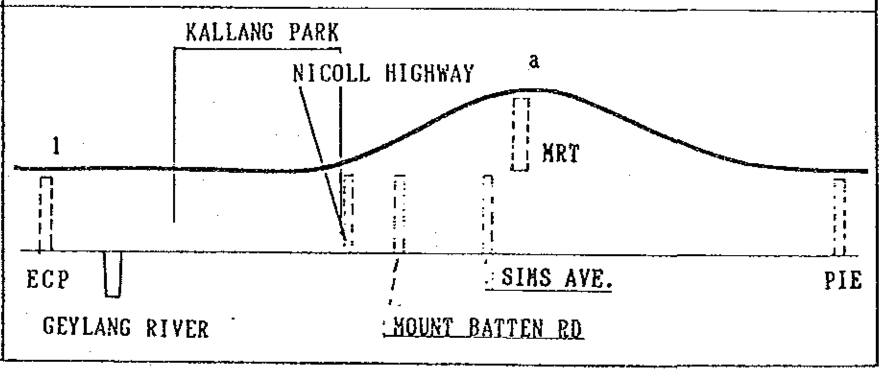
SIMBOL		PROFILE
Route I	I－1－b	
	I－1－c	
	I－2－b	
	I－2－c	
Route II	II－1－b	
	II－1－c	
	II－2－b	
	II－2－c	
Route III	III－1－a	

Fig. 6.13 Alternatives for Kallang Expressway

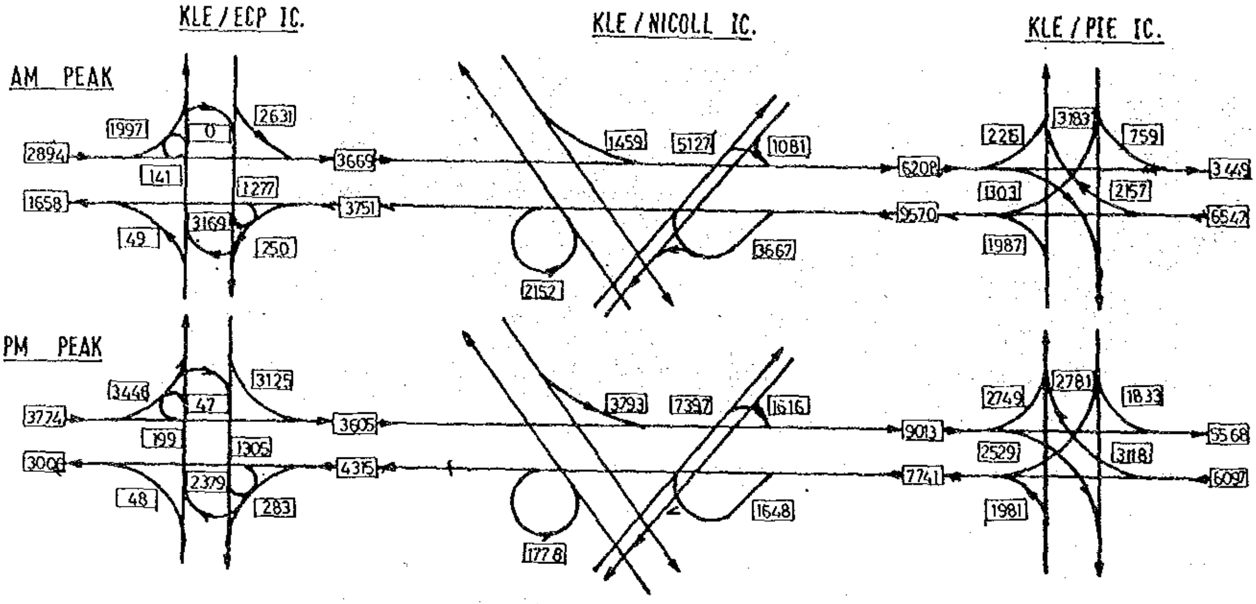


Fig. 6.14 KLE future traffic volume in 2010

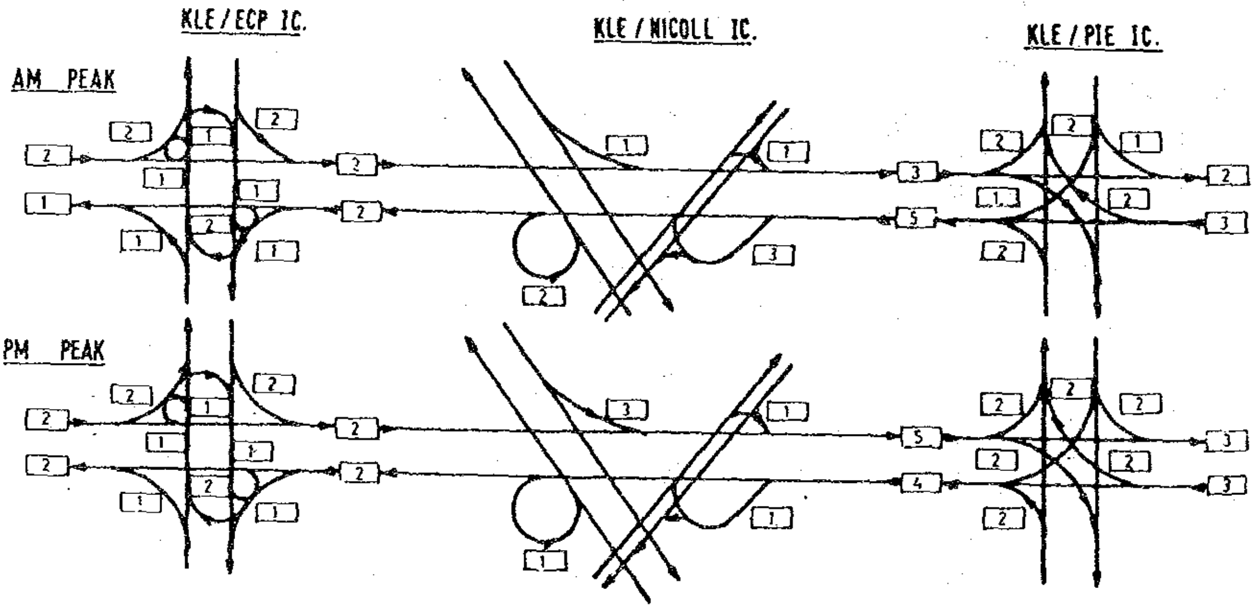


Fig. 6.15 KLE necessary number of lanes in 2010

According to the proposals both ways of passing through ECP (either from above or below) are feasible as far as alignment establishment is concerned. However, as the clearance between ordinary road and Nicoll Highway has to be ensured, the connection with MRT is deemed to be difficult. That is, since both alternatives I and II pass through MRT from the top, the gradient of the main road must be kept at the maximum value of 5% (see 9.1.1). Entering a tunnel with a gradient of 5% (towards National Stadium) is extremely dangerous. Besides, the idea of having an interchange at Nicoll Highway vicinity also may not be a feasible one. Based on the above, this alternative can be disregarded.

6.4.4 Selected Alternatives

Based on the above discussion, out of the 5 proposals established as potential alternatives, the 2 proposals of passing through the MRT from the top are disregarded and the following 3 proposals remain as targets for discussions during schematic design and evaluation.

(1) Proposed to form an interchange with ECP flyover, passes through National Stadium, Nicoll Highway and MRT from below and form an interchange with PIE by flyover. : I-1-c

(2) Proposed to form an interchange with ECP by semi-underground structure or tunnel, passes through National Stadium, Nicoll Highway and MRT from below and form an interchange with PIE by flyover. : II-1-c

(3) KLE/ECP Interchange, National Stadium, Nicoll Highway, etc. MRT, KLE/PYE/PIE IC, all connected on viaducts. : III-2-c

6.5 Alternative for PYE

6.5.1 Potential Alternatives

Although the allowance limit for route selection of PYE is wider in the area on the north of Paya Lebar Road, the stretch along Pelton Canal has been designed within a narrow width. The alternatives for horizontal alignment are centralized at 3 routes, namely, to pass across the Air Base, and to make use of the space both at Defu Avenue and Hougang Avenue. The possibilities of a longitudinal alignment for these routes are as follows (see Fig. 6.16):

1) Air Base Route

As this route passes through land which will continue to be used as an air base in the future, construction of road as a viaduct or at-grade in this area is impossible. Using a tunnel for this route is the only way.

2) Defu Avenue Route

As the majority of land passing through this route is state land on lease to HDB, PWD is likely to have free usage if adjustment is done. Moreover, as the majority of this area is used as a light industrial estate, the limitation on environmental aspects is not so stringent. Besides, as this land is able to respond to the change in land usage in future, at-grade, viaduct, and semi-covered roads are all possible alternatives.

3) Hougang Avenue Route

There are a lot of flats and apartments on the west side of the road. Moreover, the existence of private land in certain areas also limits the widening of existing roads. Flyover and semi-covered alternatives will be the backup to this alternative plan.

6.5.2 Necessary Number of Lanes

Fig. 6.17 shows the traffic volume for the interval between PYE/KLE/PIE IC and PYE/TPE IC in the year 2010.

Fig. 6.18 shows the required number of lanes for the year 2010, and there is a need to have 6 lanes on the main road of PYE.

6.5.3 Location of Interchange

There are a few types of alternative plans on the location of interchange on PYE that can be considered. Fig. 6.19 shows the alternative plans for possible interchange locations. Table 6.5 shows our point of view for each alternative plan.

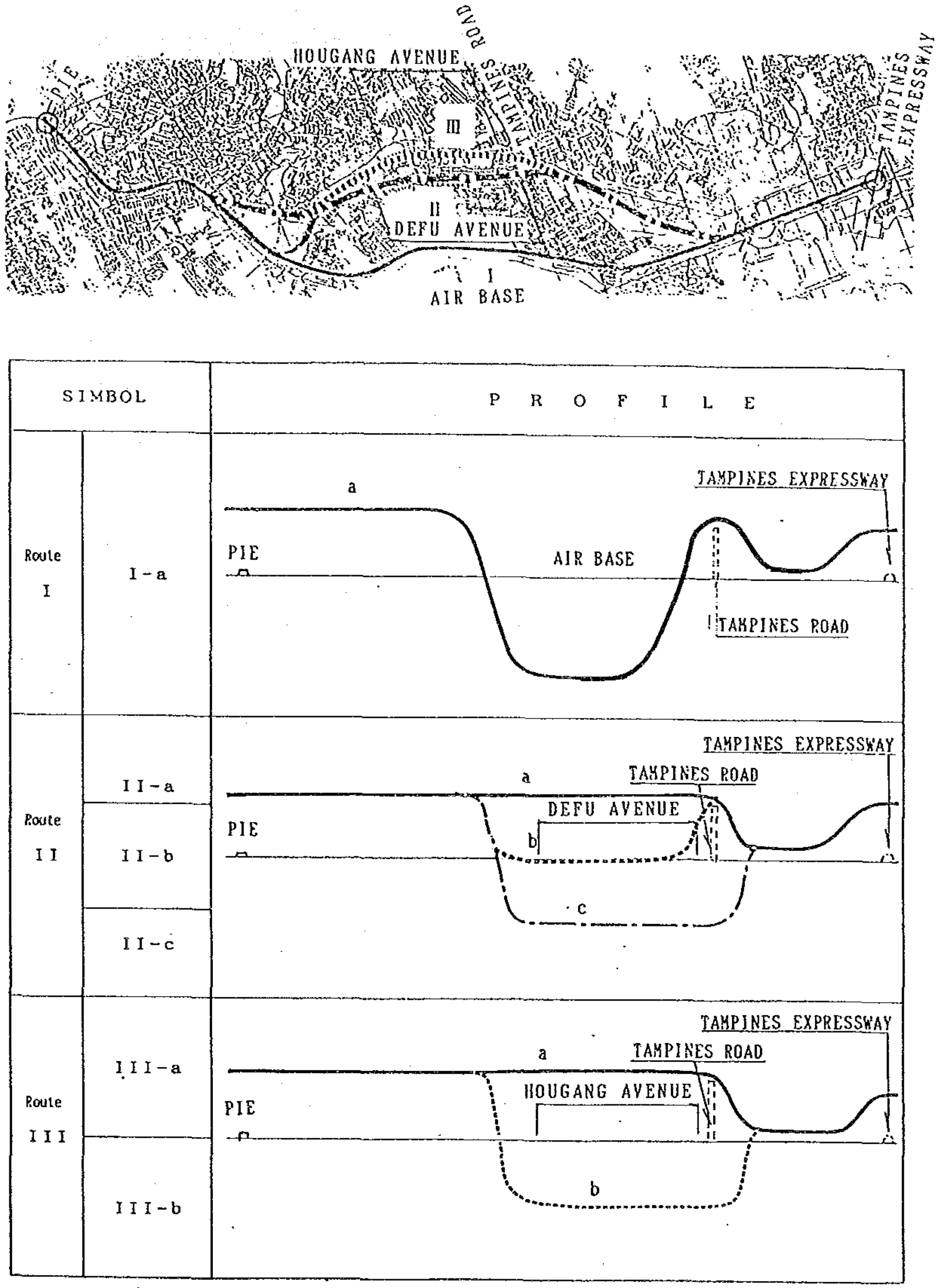
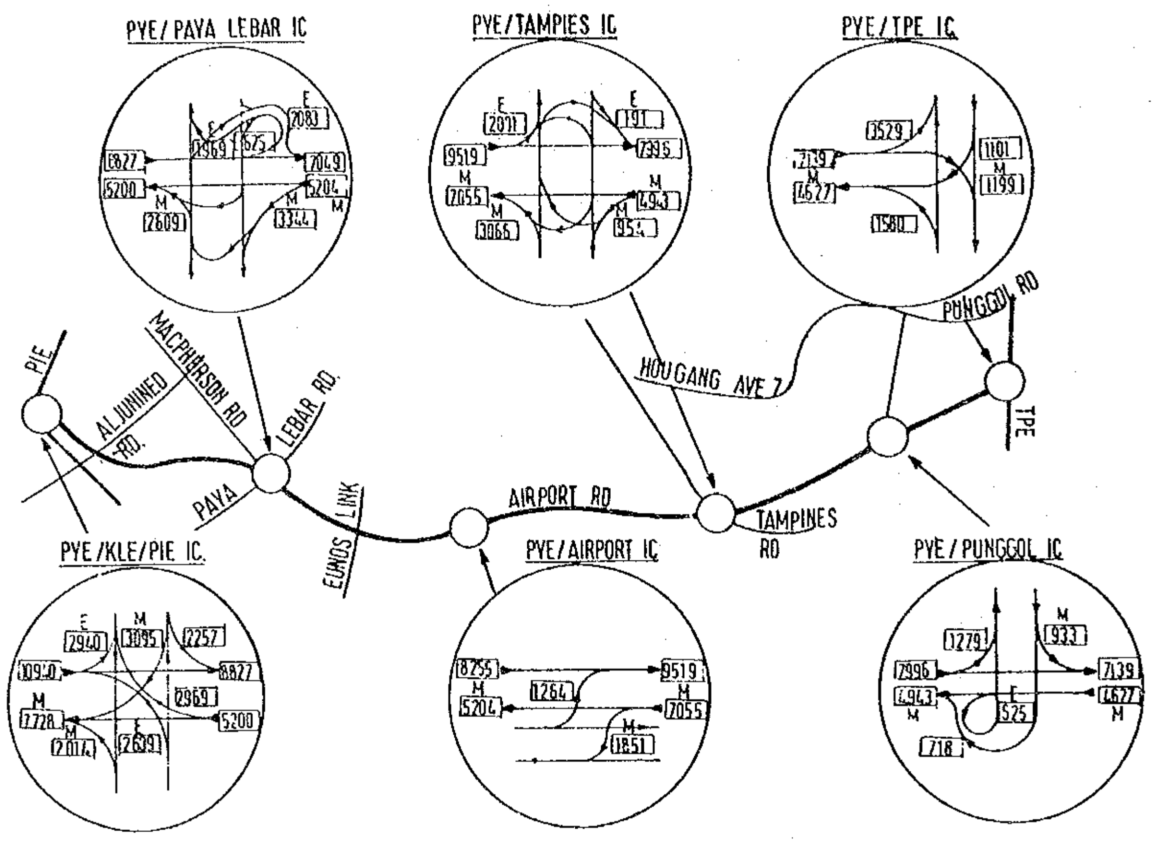
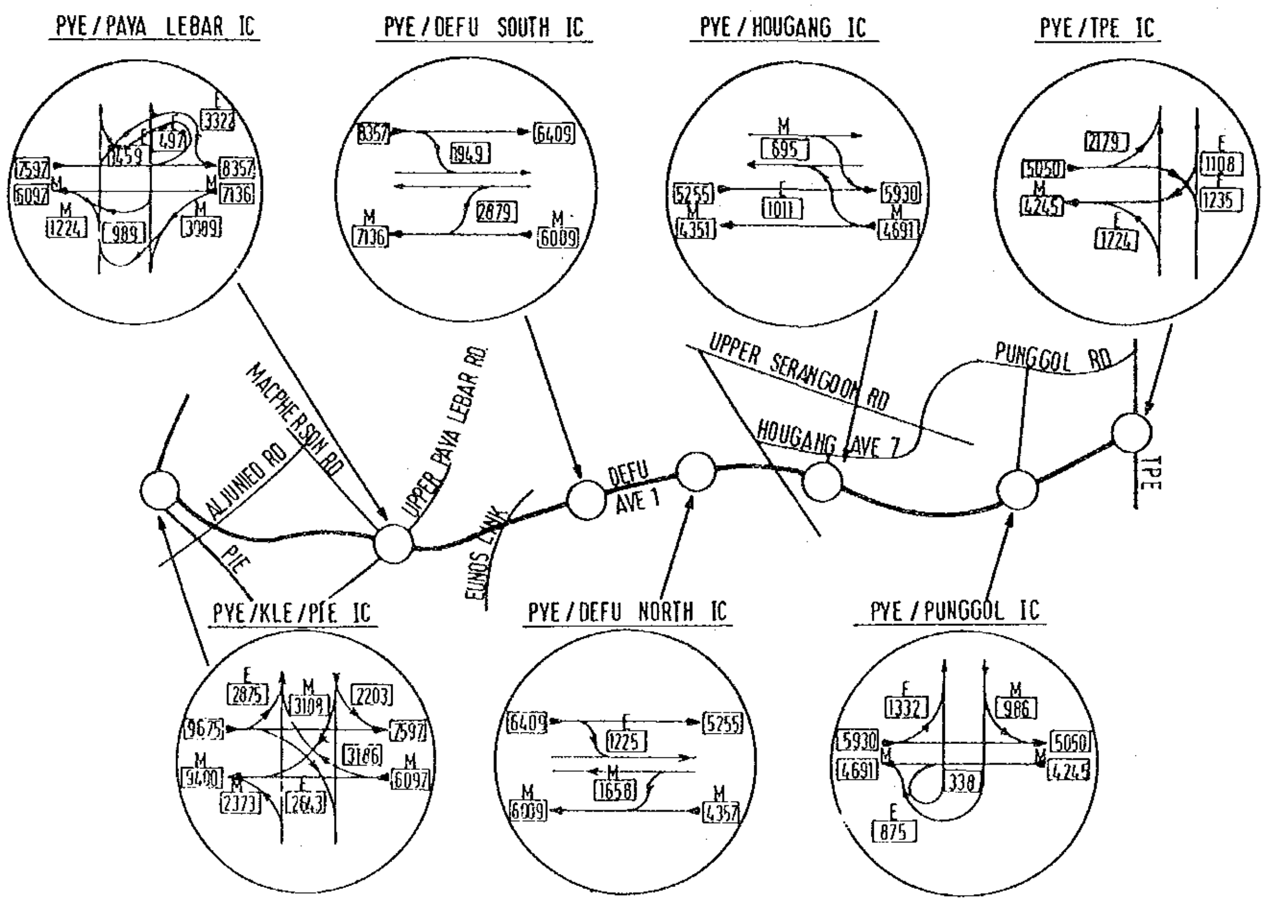


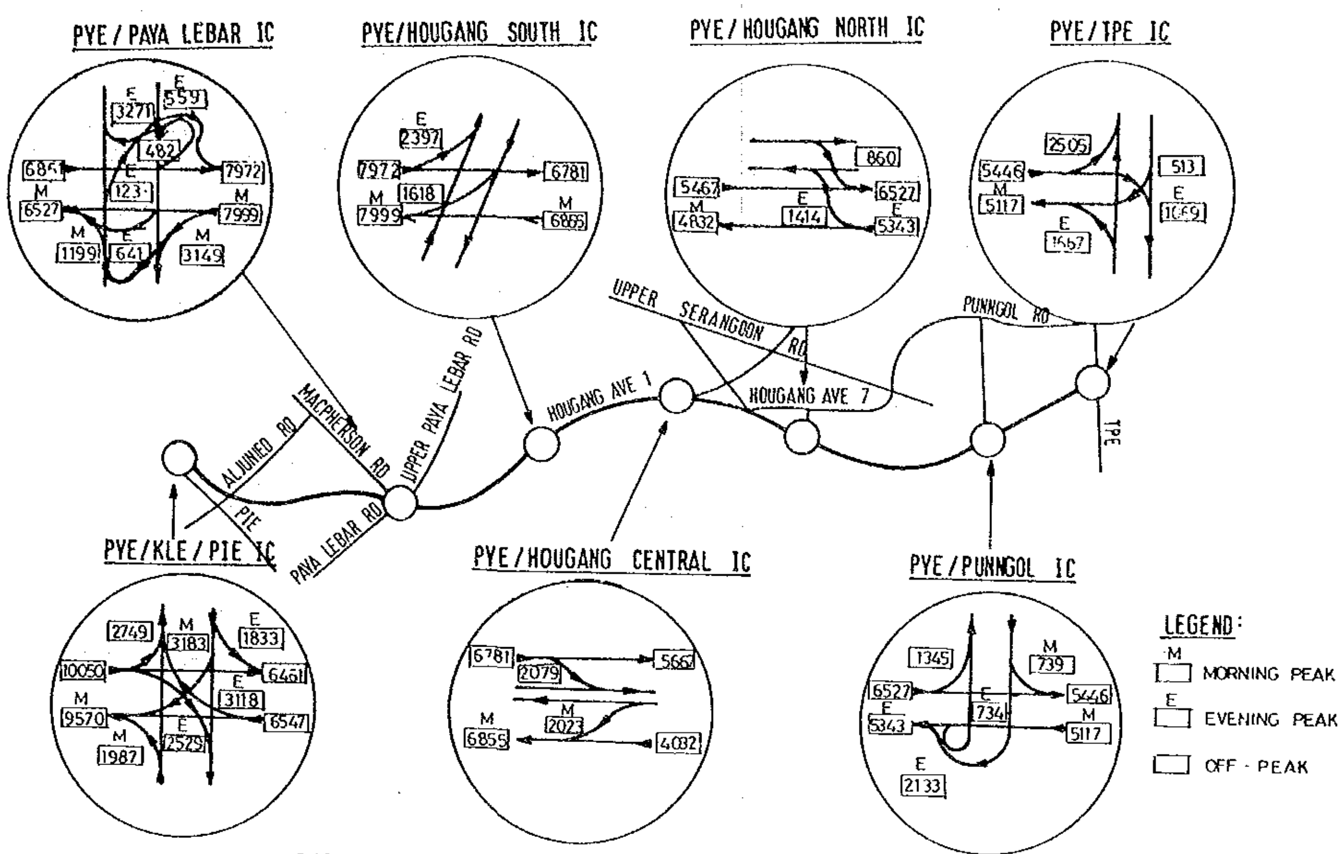
Fig. 6.16 Alternatives for Paya Lebar Expressway



PYE FUTURE TRAFFIC VOLUME IN 2010 (ALTERNATIVE I)

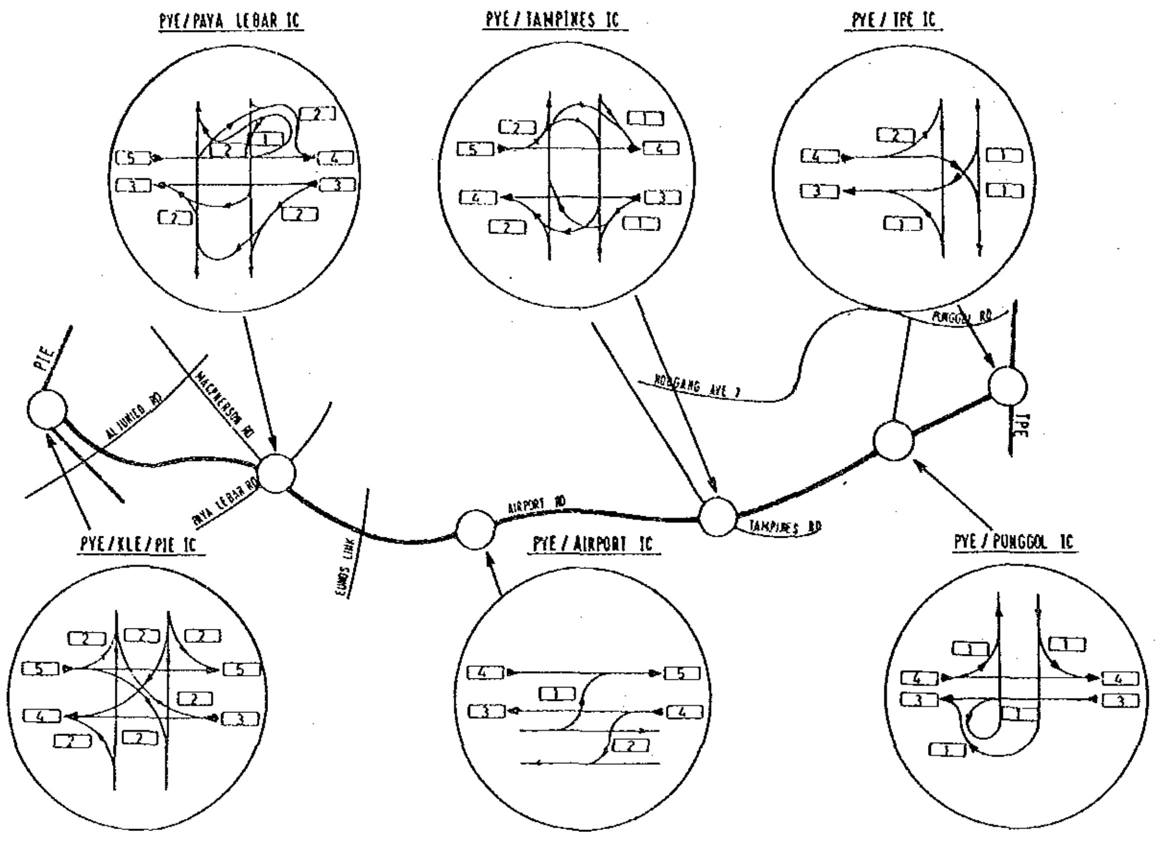


PYE FUTURE TRAFFIC VOLUME IN 2010 (ALTERNATIVE II)

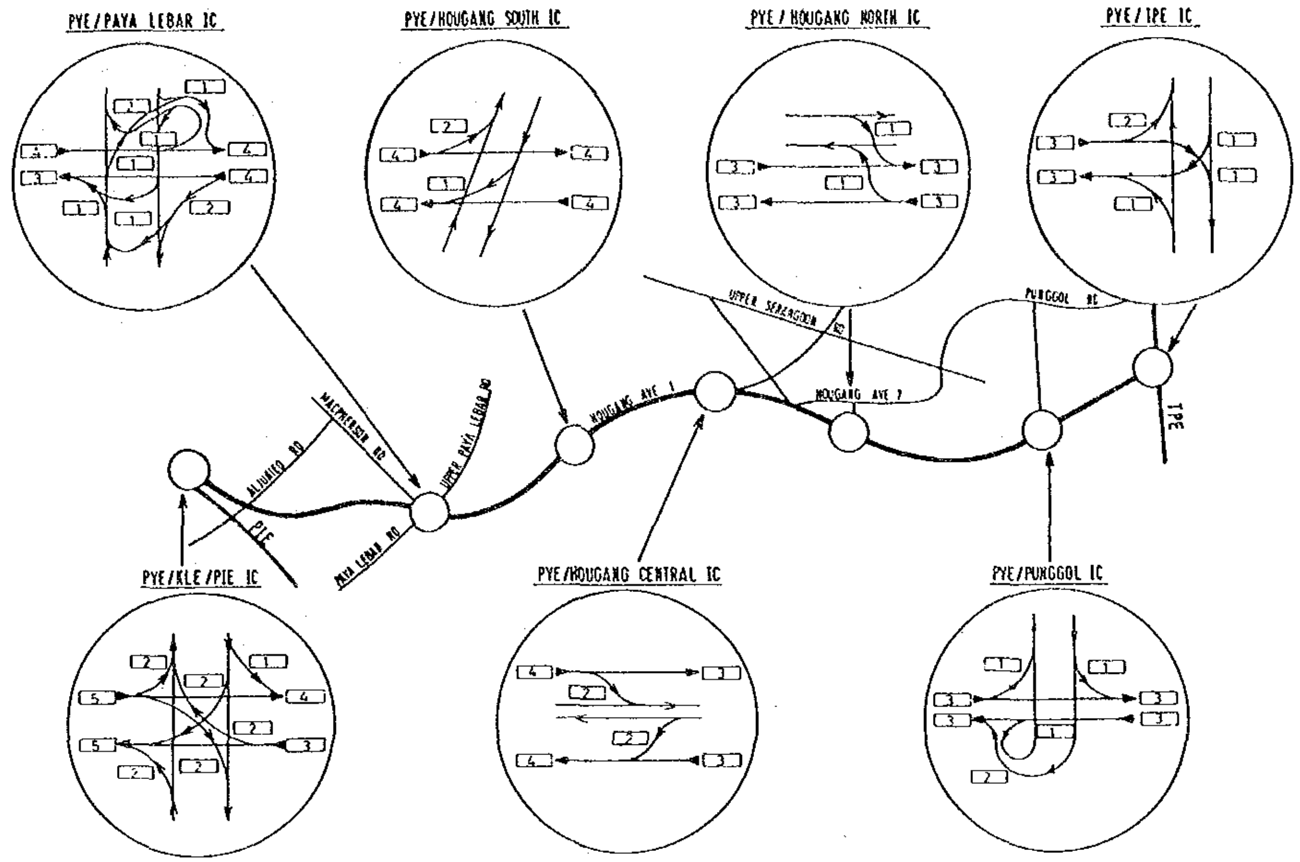


PYE FUTURE TRAFFIC VOLUME IN 2010 (ALTERNATIVE III)

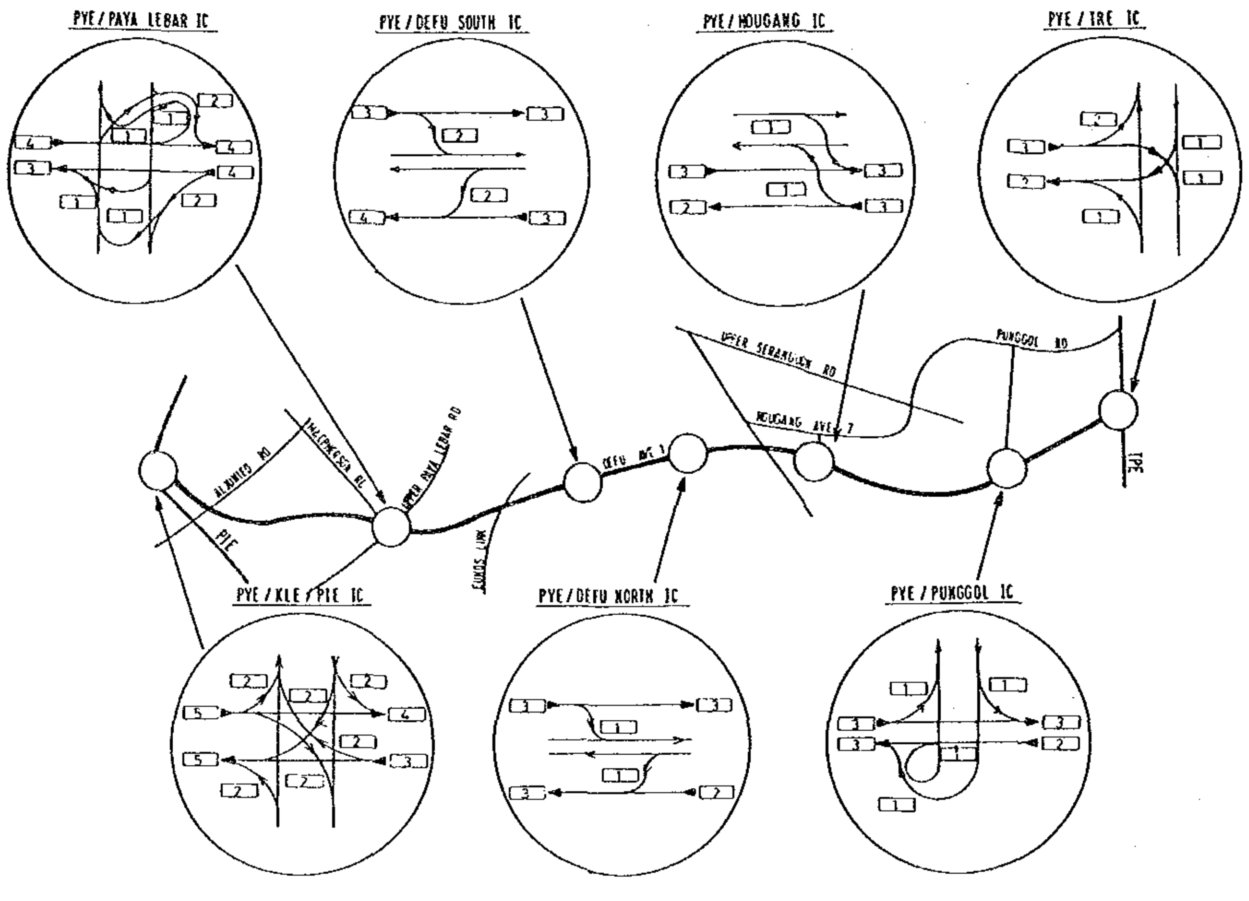
Fig. 6.17 PYE future traffic volume in 2010



PYE NECESSARY NUMBER OF LANES IN 2010 (ALTERNATIVE I)

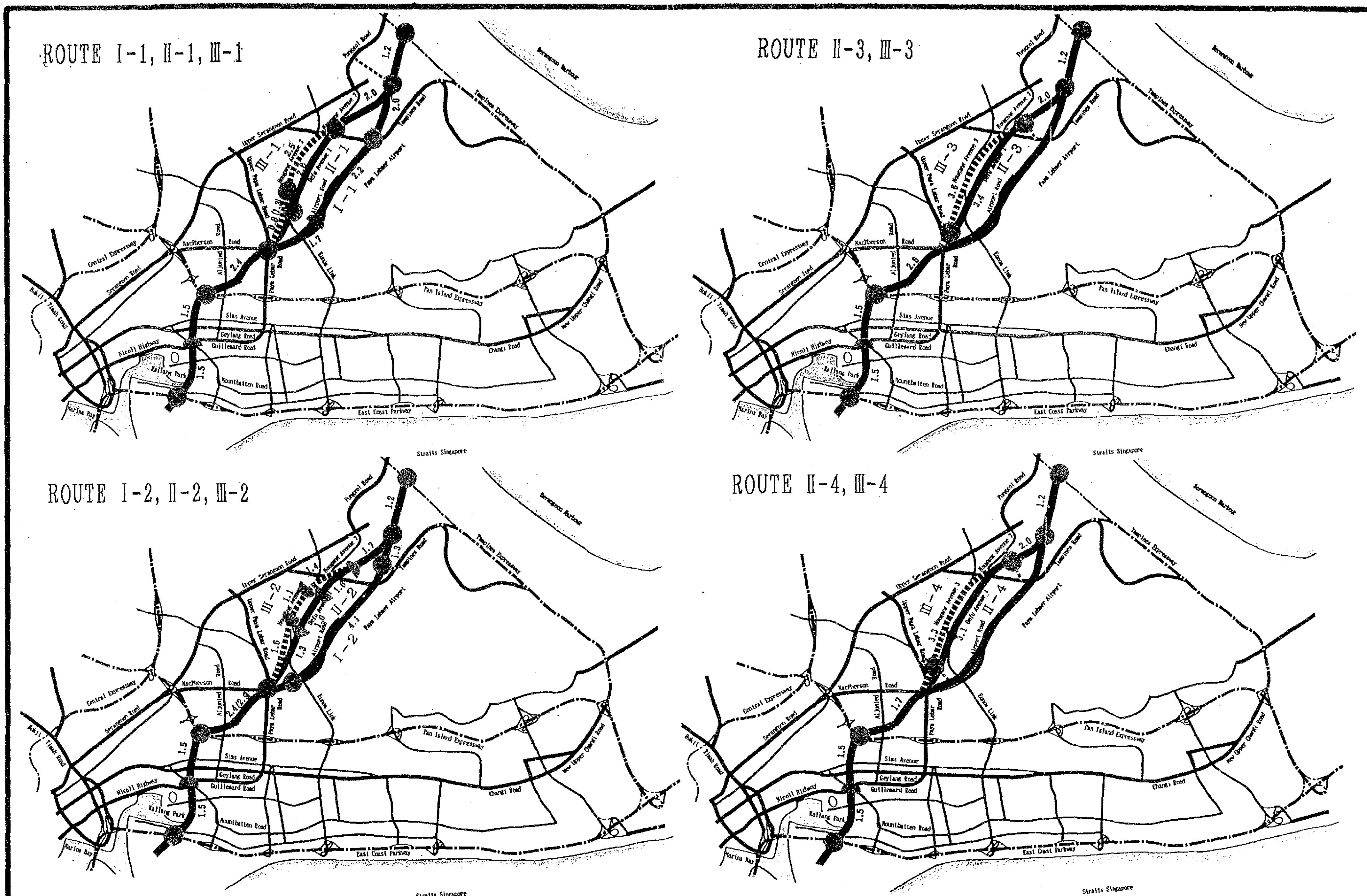


PYE NECESSARY NUMBER OF LANES IN 2010 (ALTERNATIVE III)



PYE NECESSARY NUMBER OF LANES IN 2010 (ALTERNATIVE II)

Fig. 6.18 PYE necessary number of lanes in 2010



NOTE: FIGURES INDICATE DISTANCE IN KM BETWEEN INTERCHANGES

0 5.0 km

Fig. 6.19 Arrangement of interchange

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

Table 6.5 Service function type on traffic demand of interchange alternatives

	Full Service		Partial Service	
	Concentrating Type	Distributing Type	Concentrating Type	Distributing Type
I - 1			O	
I - 2	O			
II - 1	O			
II - 2				O
II - 3	O			
II - 4		O		
III - 1	O			
III - 2				O
III - 3	O			
III - 4		O		

Note : Interval between interchanges are different between (II-1 and II-2) and (III-1 and III-3).

6.5.4 Selected Alternatives

The limitation on land use is less stringent for the Air Base route as compared to the other 2 routes. All the alternatives are included in the Schematic Design and Evaluation. As such, all the 6 potential proposals established will be discussed in the following section.

(1) Passing through Air Base via tunnel : I-a
(2) Passing through Defu Avenue via flyover : II-a
(3) Widening of Defu Avenue (ground structure) : II-b
(4) Passing through Defu Avenue via semi-underground structure : II-c
(5) Passing through Hougang Road via flyover : III-a
(6) Passing through Hougang Road via semi-underground structure : III-b

CHAPTER 7

SCHEMATIC DESIGN FOR ALTERNATIVES

CHAPTER 7 SCHEMATIC DESIGN FOR ALTERNATIVES

7.1 PIE

7.1.1 Route Alignment

For the route alignment improvement of PIE , consideration is paid to the protection of existing structures as well as arrangement of structures to be built or reconstructed.

1) Alternative for widening at even grade

Since there is no particular control point and there is a good streamlining on the existing alignment between PIE/BKE IC to PIE/Mt. Pleasant IC, adding one lane on both sides of the existing road is possible. At the stretch near PIE/Mt. Pleasant IC where the existing alignment appears bad with a curve radius of less than 300m, separated widening is proposed by setting circle to a radius of 400m. This will allow a design speed of 80 km/h and the westward residential area will be avoided. There are residences, a school and a flyover which must be avoided between PIE/Mt. Pleasant IC and PIE/Thomson IC. It is necessary to widen towards the north side at PIE/Thomson IC separately. In the stretch from PIE/Thomson IC to PIE/CTE IC, route alignment consists of 5 to 6 lanes per one direction because of succeeding merging and diverging ramps. A change in the course of the canal is not required. Vertical alignment is according to the existing level because of at-grade widening.

2) Alternative for viaduct by-passing on both sides of the PIE

This is a 2-lane one way viaduct and it is proposed on the existing PIE. At the stretch near PIE/Mt. Pleasant IC, route alignment has to be schemed to attain speed performance by improving the existing curvature of less than 300m radius as well as improving the layout inside the Right Of Way. In this Alternative, the viaduct passes over the PIE longitudinally with a profile that follows the existing road and a design speed of 80 km/h is maintained. In the case of the viaduct merging with the PIE at ground level to the west of PIE/Thomson IC, alignment is arranged so as to avoid the canal which is under construction.

7.1.2 Improvement of Interchanges

The study area of the PIE route can be divided into 2 sections, the west which has hilly terrains and the east which consists of urban areas that include various town facilities with severe restrictions for land acquisition.

Types of interchange are basically the same as existing based on the results obtained from the traffic analysis.

1) Principles of at-grade widening

At-grade widening complies with the following principles;

(1) In the case of an interchange where the PIE passes under the crossing of the over-bridge, the following 2 methods may be applied depending on the adequacy of vertical clearance and the life span of the over-bridge to date.

(a) To demolish the over-bridge and construct a new over-bridge with wider clearance,
(b) To construct a new structure so as to accommodate lane widening on the newly aligned course beside the current PIE route.

(2) In the case of an interchange where PIE passes over the crossing of the roadway, the following 2 methods may be applied.

(a) To add partial structures to the required width at the side of the existing flyover to be widened.
(b) To construct a new flyover to accommodate lanes widening side by side, i.e., close to the existing PIE.

(3) If the widening of lanes at the interchange forces the access rampways outside the Right Of Way and into unavailable land, the *shape of the rampway can be reformed to adjust to the widening* lanes.

(4) The way of widening in the through traffic roadway conforms to the improvement plan of horizontal alignment by means of grade separated or both-side widening at ground level of the roadway section.

(5) In the grade separated widening section, horizontal curve radius is enlarged to smoothen traffic flow, while median relocation, earth works, and retaining walls are included in the construction work.

2) At-grade widening at interchanges

Specified description on structural planning of at-grade widening is displayed herein with respect to PIE interchanges. Table 7.1 indicates the existing situations of interchange structures.

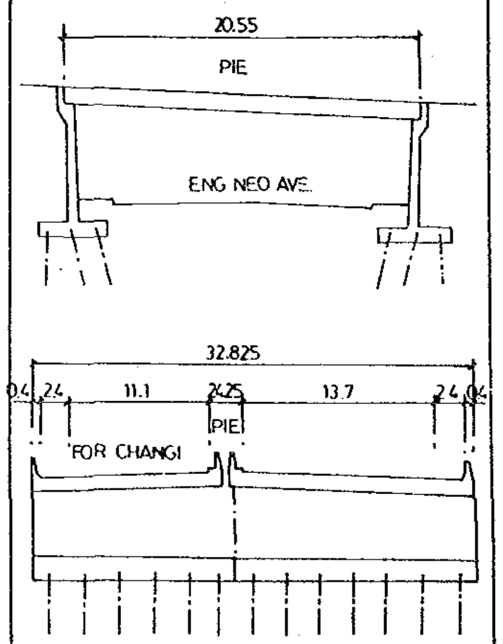
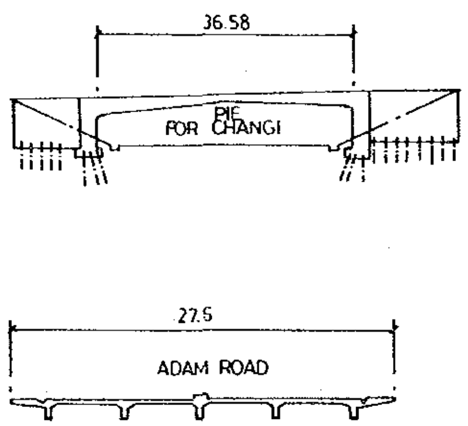
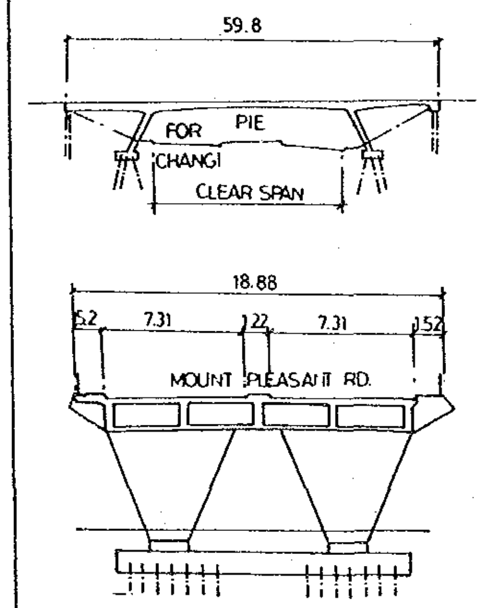
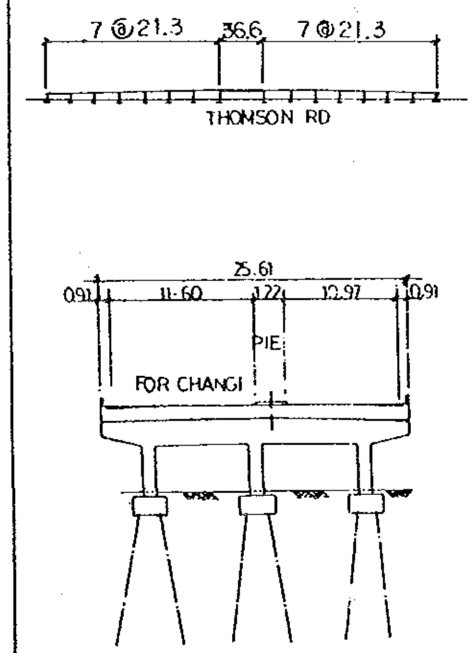
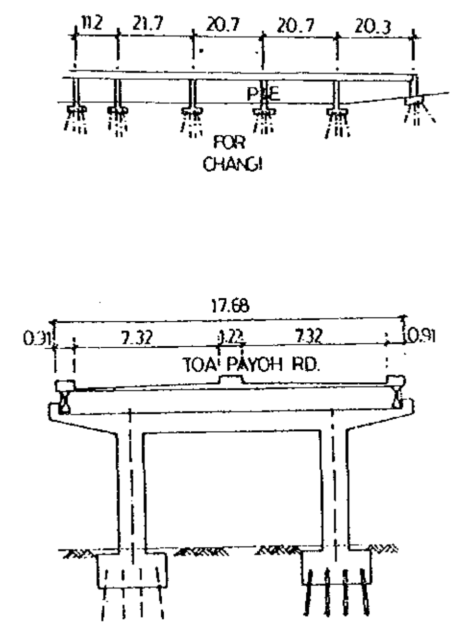
(1) PIE/Eng Neo IC (Fig. 7.1)

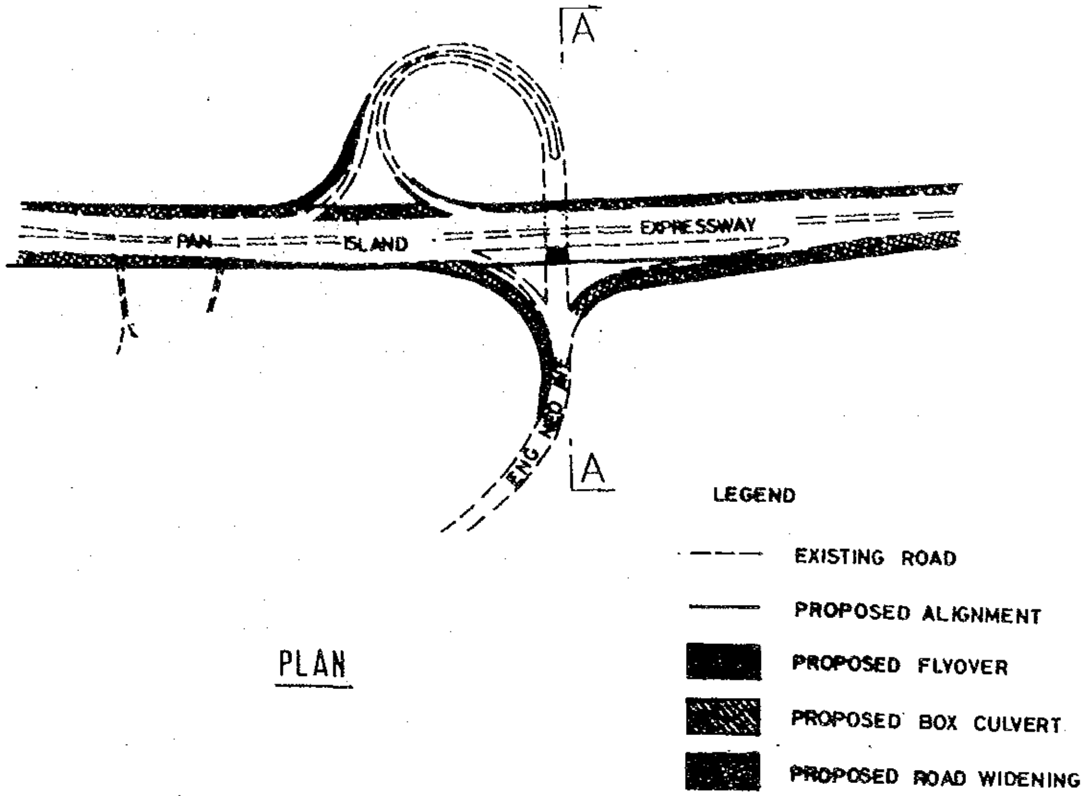
PIE passes over the crossing of PIE/Eng Neo Avenue. This flyover consists of a simple span slab bridge with PC beam. It can be widened by constructing additional sections of the superstructure and the substructure to the required width at both sides of the existing structure. Adding concrete to the bridge abutment should be preceded by the demolition of wingwall and the foundation work so as to support the widened portion of the abutment. After the PC I-beams are placed, concrete is used to fill up the space till 1/3 of the beam's depth. It is then bound with the existing beam slab by reinforcing bar to be tied in the same way as the existing slab. Access rampways would shift outward to a distance of the widening offset. No additional land acquisition is required.

(2) PIE/Adam IC

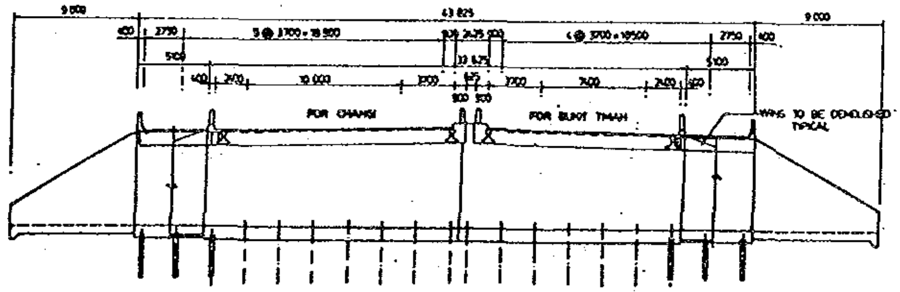
PIE passes under the crossing of Adam Road by over-bridge. Horizontal clearance below Adam Road is too low to accommodate widening of lane to the same configuration of interchange as the existing one. On the

Table 7.1 Type of existing flyovers

		Eng Neo FO	Adam FO	MT.Pleasant FO	Thomson FO	Toa Payoh FO
TYPE	Super-structure	Precast Concrete Beam (pretensioning system)	Rigid Frame Structure (Post-tensioning System)	Rigid Frame Structure (Post-tensioning System)	Precast Concrete Beam (post-tensioning system)	Precast Concrete Beam (post-tensioning system &RC)
	Substructure	Reversed T-type Abutment			Reversed T-type Abutment Rigid Frame Pier	Reversed T-type Abutment Rigid Frame Pier
	Foundation	H-Section Steel Pile	H-Section Steel Pile	H-Section Steel Pile	H-Section Steel Pile	H-Section Steel Pile
Bridge Length		20.55m	41.78m	59.8m	335.3m	
Span Length		20.0m	36.58m	13.7+32.0+13.7	36.6m,21.3m(standard span)	21.7,20.7,20.3,≒11.2m
Clear Span		19.4m	36.58m	32.0m		
Remarks						
Sketch						



PLAN



A-A CROSS SECTION

Fig. 7.1 Eng Neo Interchange

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

grade-separated widening, a structure with a clear span of 22m long, as shown in Fig. 7.2, is proposed instead of a box culvert.

The 22m structure will accommodate a 4 lane carriageway through the approaching embankment to the south side of the Adam over-bridge. The proposed structure is of a girder bridge having a 1m depth PC precast beam.

In this alternative the south side rampways on the PIE down-line would shift towards the south and thus additional land acquisition is necessary. It will also shift rampways apart from the through lanes and widened lanes are added instead of relocating the rampway. Rampways are to be accommodated in the box culverts placed at the back of the abutment as shown in Fig. 7.3. This alternative is recommended for economical reasons as there is no necessity for land acquisition. (refer to Appendix 7.3)

(3) PIE/Mt. Pleasant IC (Fig. 7.4)

Mount Pleasant Rd. is on a strutted rigid frame over-bridge, where PIE passes under it. There is insufficient clearance height to accommodate the widened lanes, and a clear span structure is necessary by cutting through the approach embankment of Mt. Pleasant Road. To smooth alignment in the process of improvement, a PC precast beam girder bridge is proposed on the north approach at the concave curve of the horizontal alignment. Access rampway should be shifted. Median relocation due to change of lane direction is needed for a long stretch, ranging 700m long approximately. However, land acquisition is not necessary.

(4) PIE/Thomson IC (Fig. 7.5)

PIE passes over the crossing of Adam Rd. which consist of 6 lanes. The viaduct is made up of 14 spans, consisting of PC precast girder bound in transverse prestressing, which does not allow widening of girders at the sides.

Roadway widening has no improvement on the alignment, as the widening side is fixed to the north of the viaduct, where PIE alignment has a convex bend. Widening lanes for up-line direction have a new viaduct with the same form and proportional scale. Due to the grade-separated widening towards the northern side, access rampways connecting to Changi bound lanes should be relocated. Median shifting will range for 1 km approximately. No land acquisition is needed.

(5) PIE/Toa Payoh IC (Fig. 7.6)

Rampways connecting to Bukit Timah bound lanes of the PIE, cross over the PIE at the ground level section. The Toa Payoh over-bridge has insufficient vertical clearance and not enough clear span for widening. Toa Payoh over-bridge can be refurbished at the same time as the widening. It is proposed to add 1 lane each at both sides of the carriageway.

For the rampways that cross over the canal on the south of PIE, rampways travel on viaducts and then onto the prescribed over bridge. Rampways on viaducts are also proposed to be reconstructed during widening works. In order to attain the specified radius for loop rampways, the Right of Way must be expanded to the south. This does not require land acquisition.

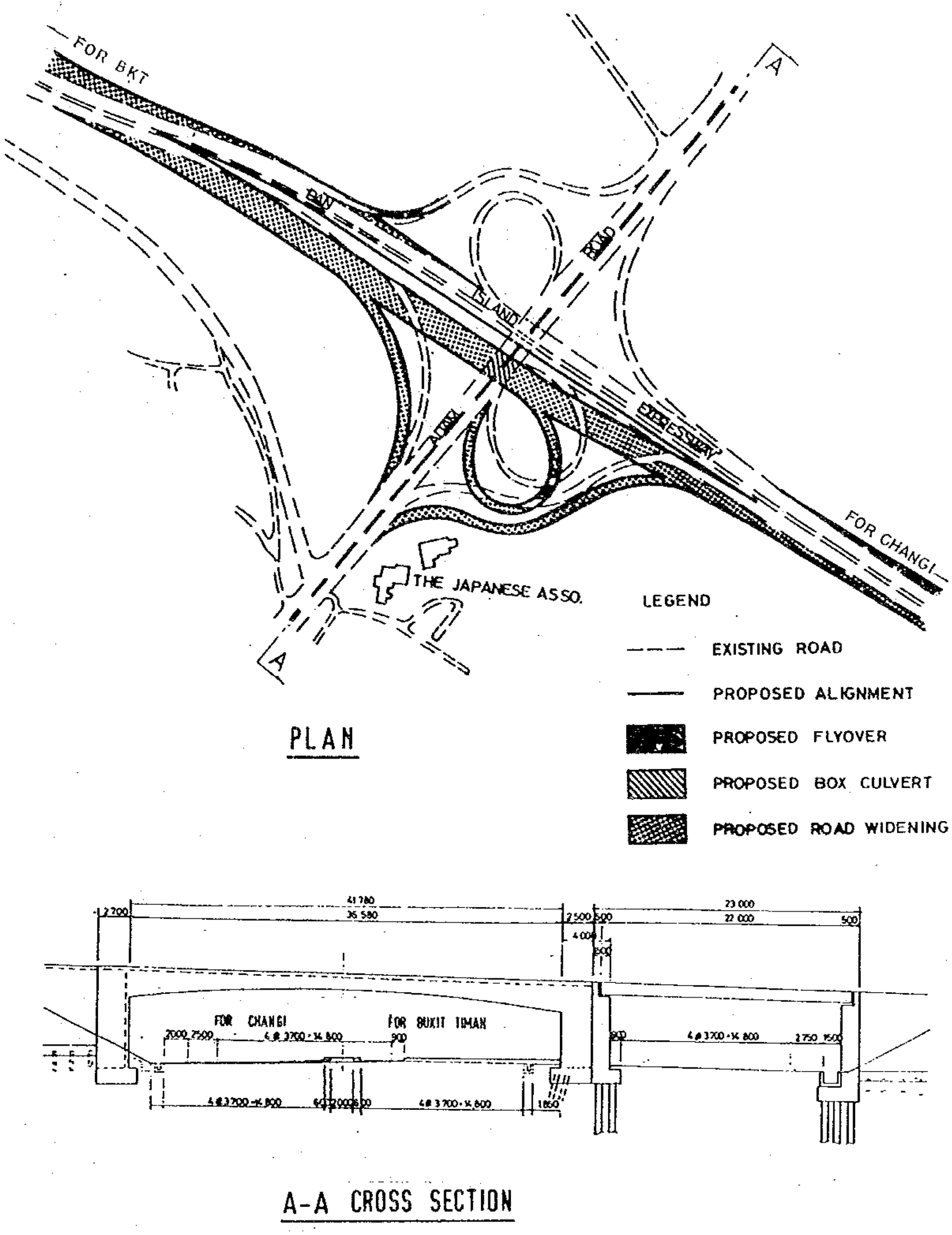
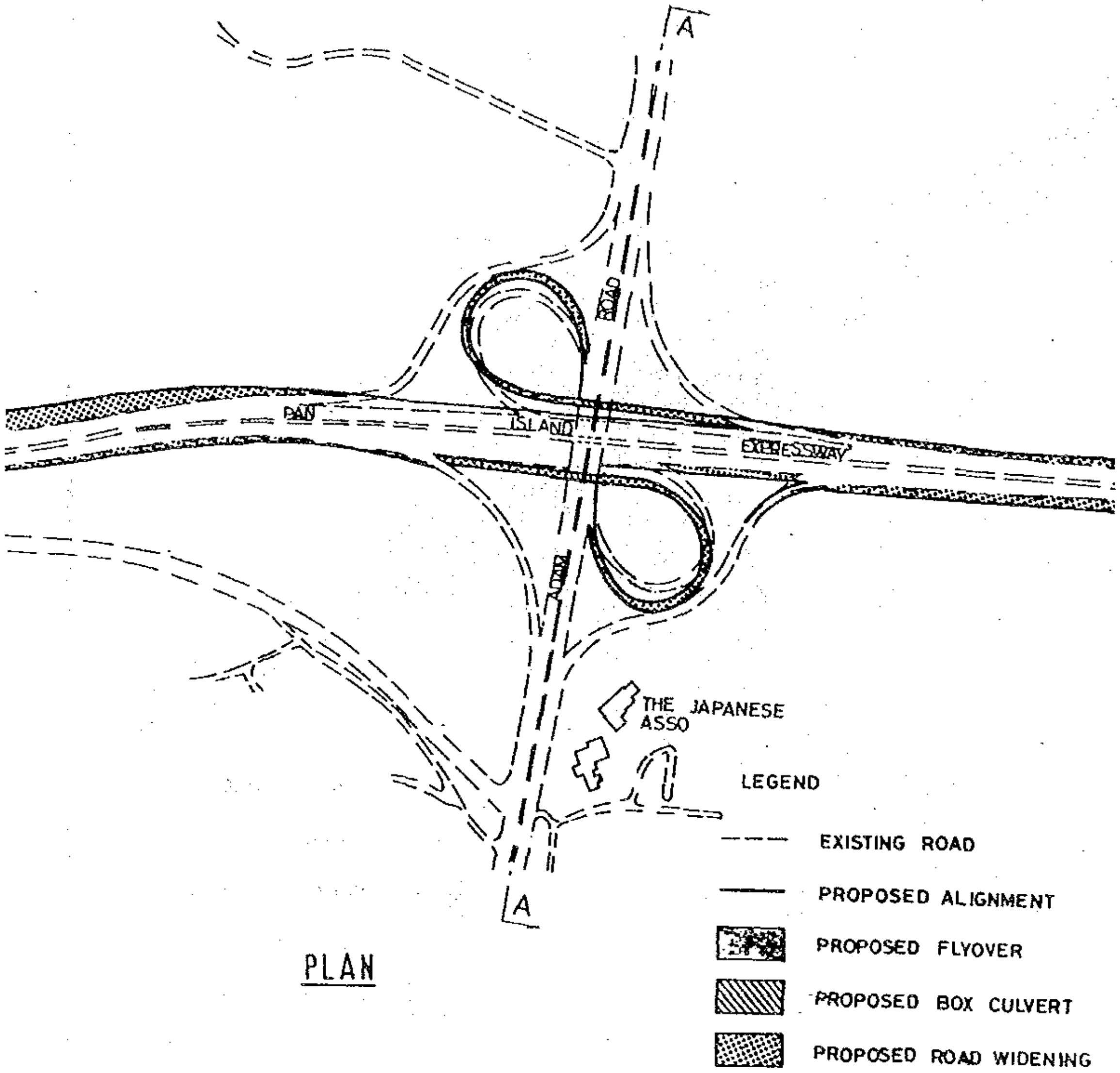
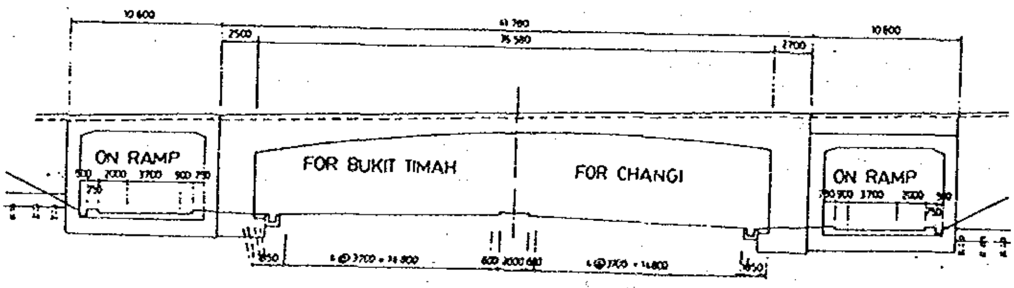


Fig. 7.2 Adam Interchange (1)



PLAN



A-A CROSS SECTION

Fig. 7.3 Adam Interchange (2)

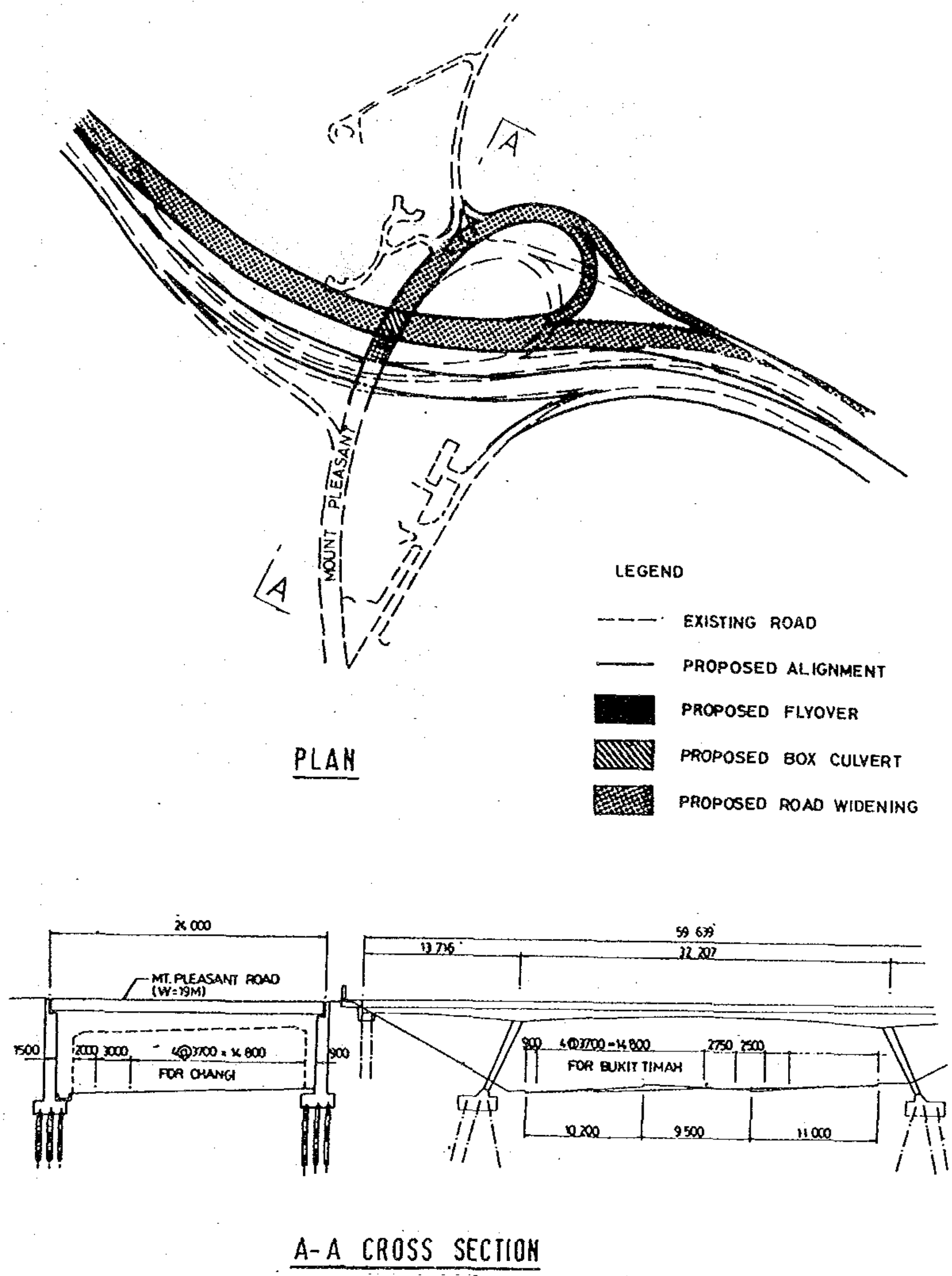
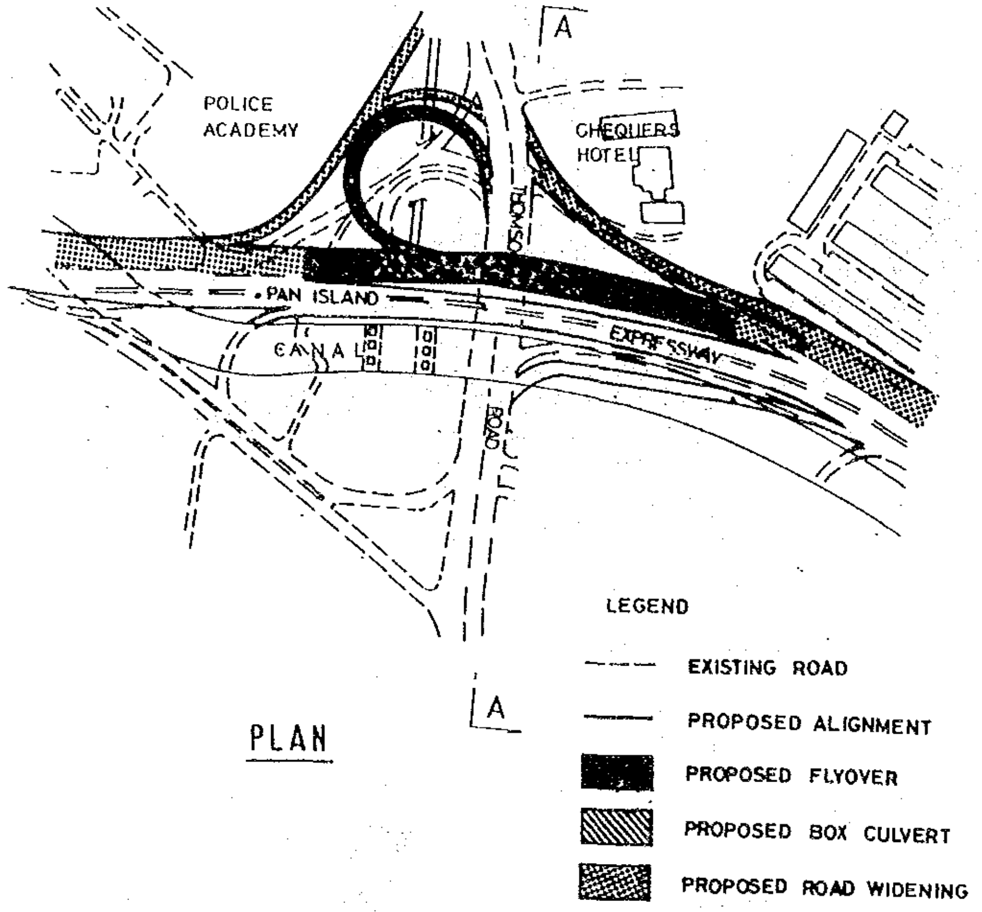


Fig. 7.4 Mount Pleasant Interchange



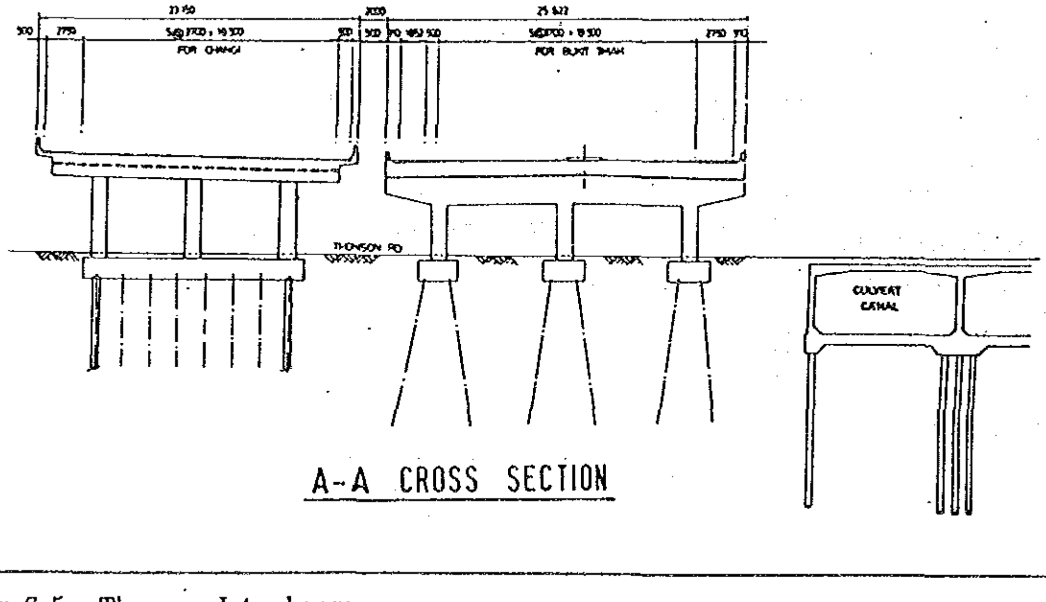


Fig. 7.5 Thomson Interchange

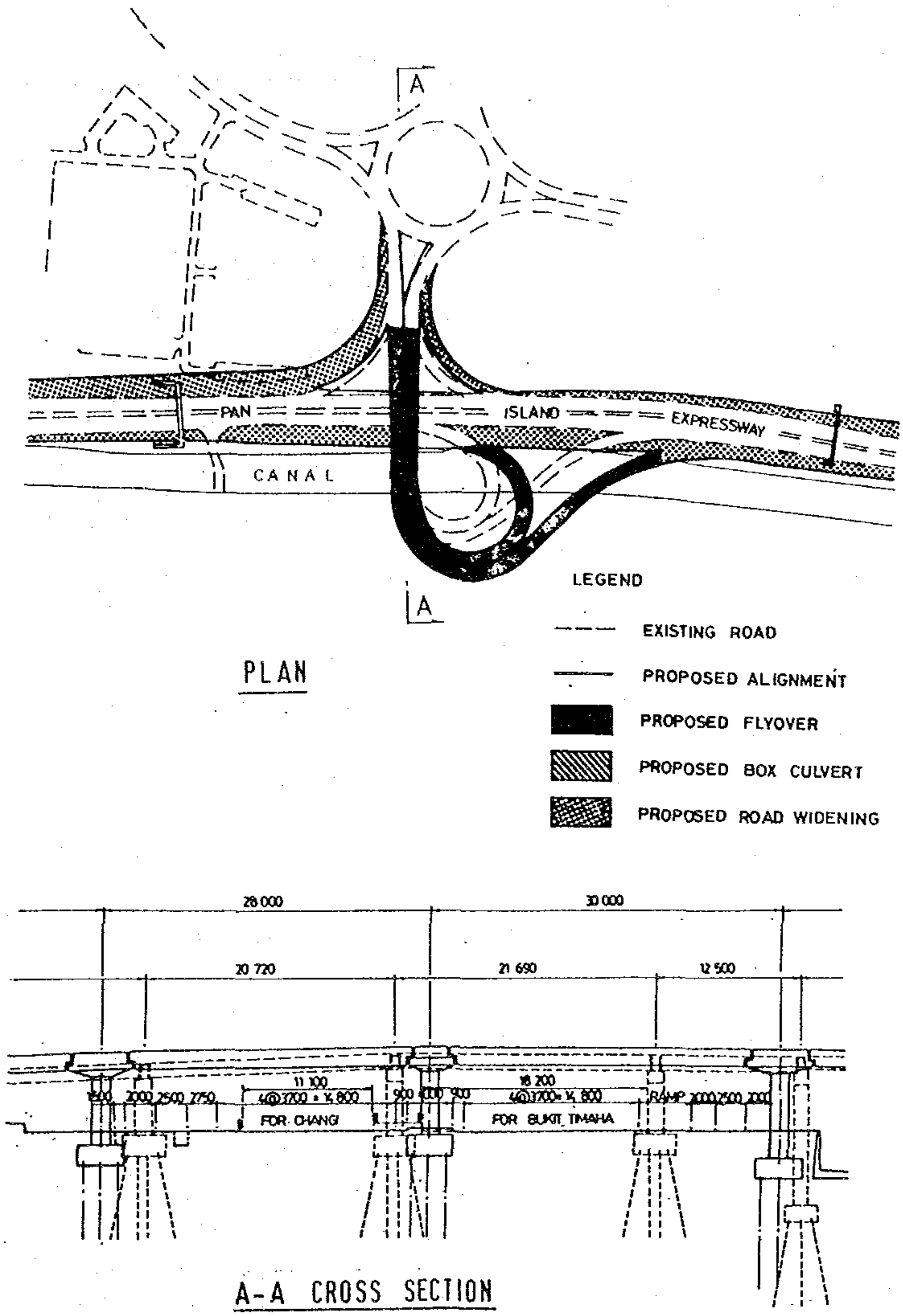


Fig. 7.6 Toa Payoh Interchange

3) Viaduct alternative

Structure planning for viaduct alternative is described herein. Structural form of viaduct is classified into the following types,

(a) To pass through interchange area (Fig. 7.7).
(b) To run parallel to the throughway section (Fig. 7.8)
(c) To merge with the ground level (Fig. 7.9).

The greatest advantage of the viaduct alternative is that there is no need to change the locating ground, but only columns are required to support the viaduct. Utilizing this advantage, column locations are chosen in "Slope Reserve" and mediate area within interchange in the Right of Way.

Piers are not positioned on the median unless alignment improvement and reasonable span length are secured. Land space for future widening of PIE at grade elevation is also reserved by avoiding pier locations.

Superstructure is proposed to consist of PC precast beam with a 25m long span for economy and quick erection. Piers supporting the superstructure are proposed to consist of cross-head type with round cross-sectional columns for easy building and superior appearance. Foundation structure is proposed to consist of piled foundation considering existing structure and geological conditions.

Merging section of viaduct to the ground level roadway is at a singular point, hence the existing roadway of the PIE has to be changed in a wide range at two locations.

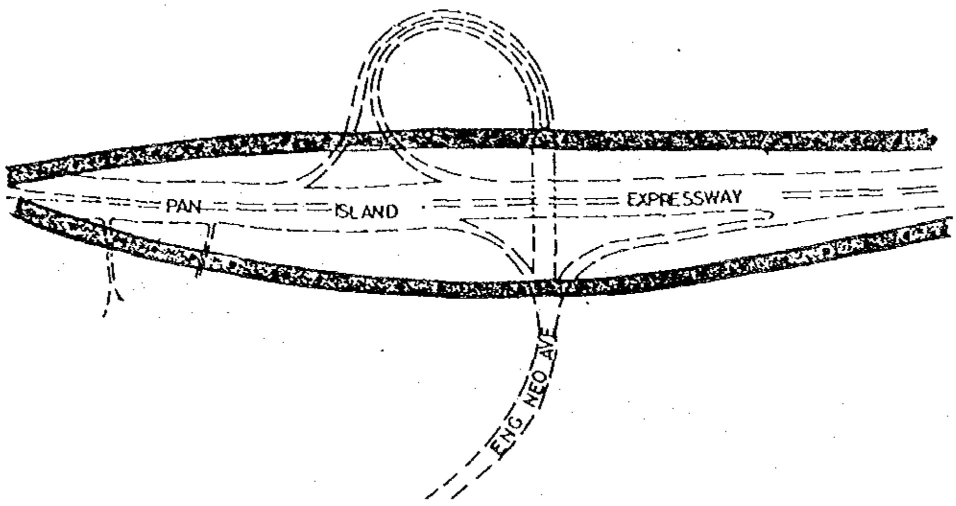
Viaducts on the outer lanes of the PIE join the ground level and then converge to the inside lanes of the PIE instead. The merging section is in the form of a slipway. On the transition section from outer lanes to inner lanes of the PIE, skew crossing over the PIE carriageway requires girder bridges in a middle scale span. A bent supporting type of construction method is recommended and cast-in-situ prestressed concrete box girder is used to serve traffic lanes under falsework as shown in Fig. 7.10.

4) Close construction

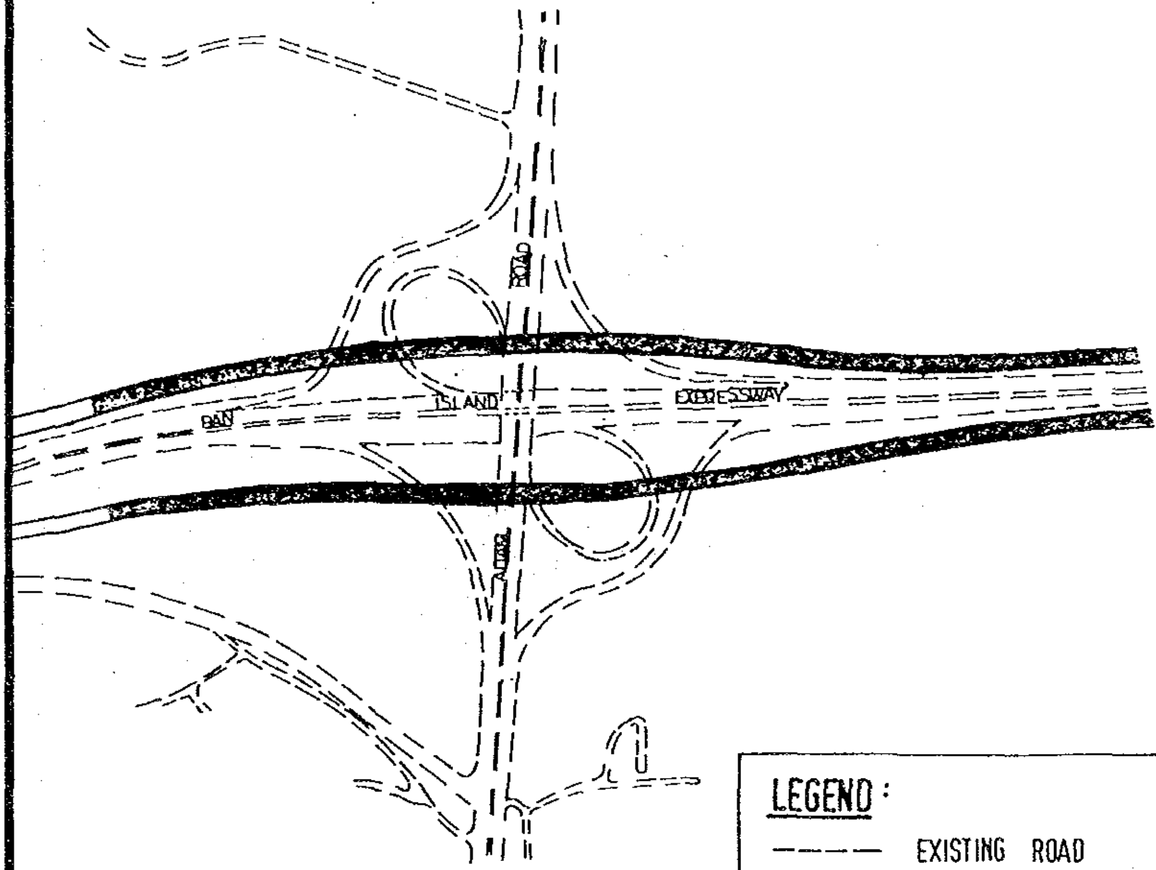
A complicating situation exists at the location where the Off Ramp from PIE down-line lane at PIE/Toa Payoh IC crosses over the canal. This is further aggravated by the MRT shielded tunnel of double tube 5.5m in outer diameter as shown in Fig. 7.11. The presence of the MRT system prevents effective displacement of vibration and therefore the *foundation work has to be carried out by vibration free method preceded* with hardening of surrounding ground by soil stabilization.

Another problematic point is at the pier locations in PIE/Thomson IC proposed in the viaduct alternative. There is a very narrow spacing of 4 to 5m between the existing PIE flyover and covered canal.

Large diameter pier foundations are proposed by applying the Reverse Circulation Drill Method enabling narrow space construction as shown in Fig. 7.12.



PIE / ENG NEO IC



PIE / ADAM IC

LEGEND:

------	EXISTING ROAD
———	PROPOSED ALIGNMENT
•	PROPOSED PIER

Fig. 7.7 Type of viaduct passing over interchange area

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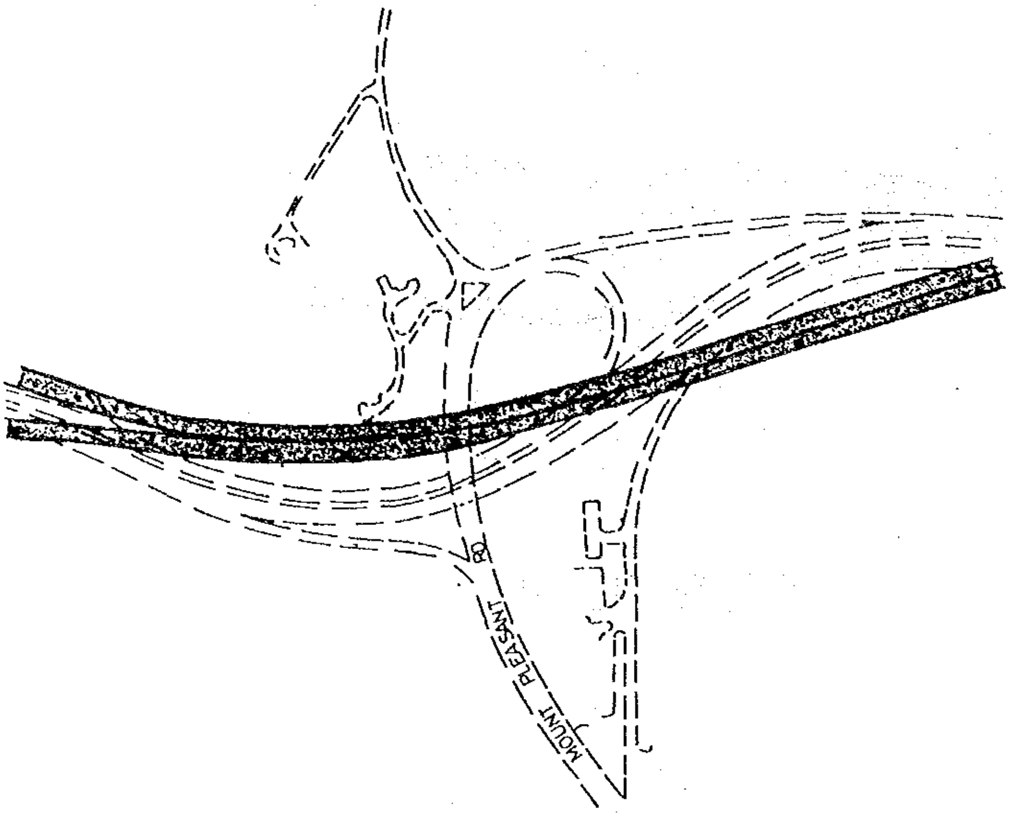
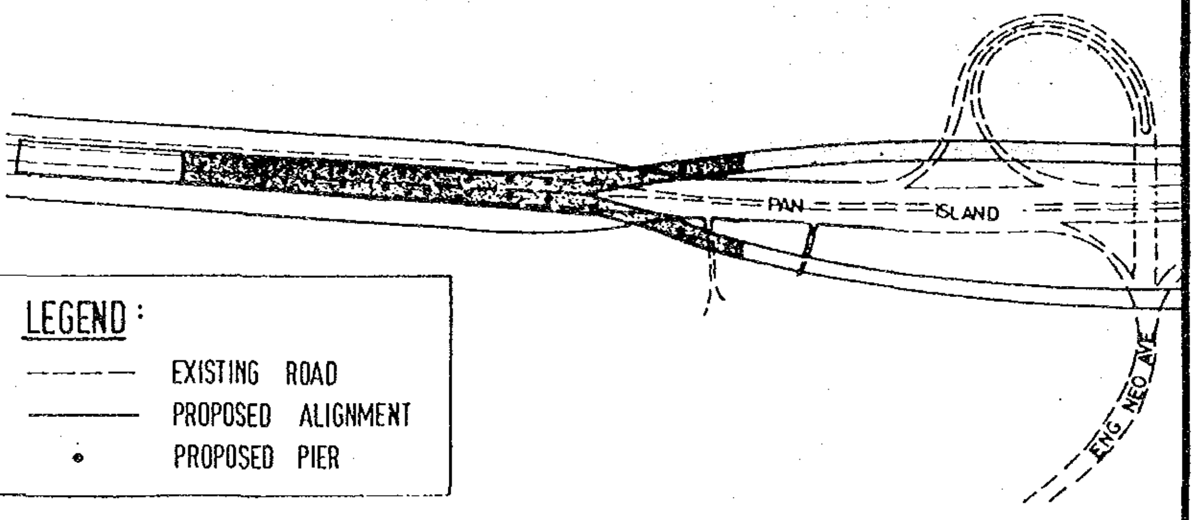


PIE / MOUNT PLEASANT IC



LEGEND :

- - - - EXISTING ROAD
——— PROPOSED ALIGNMENT
• PROPOSED PIER

PIE / ENG NEO IC

Fig. 7. 8 Type of viaduct running parallel to the throughway section

Fig. 7. 9 Type of viaduct merging to the ground level

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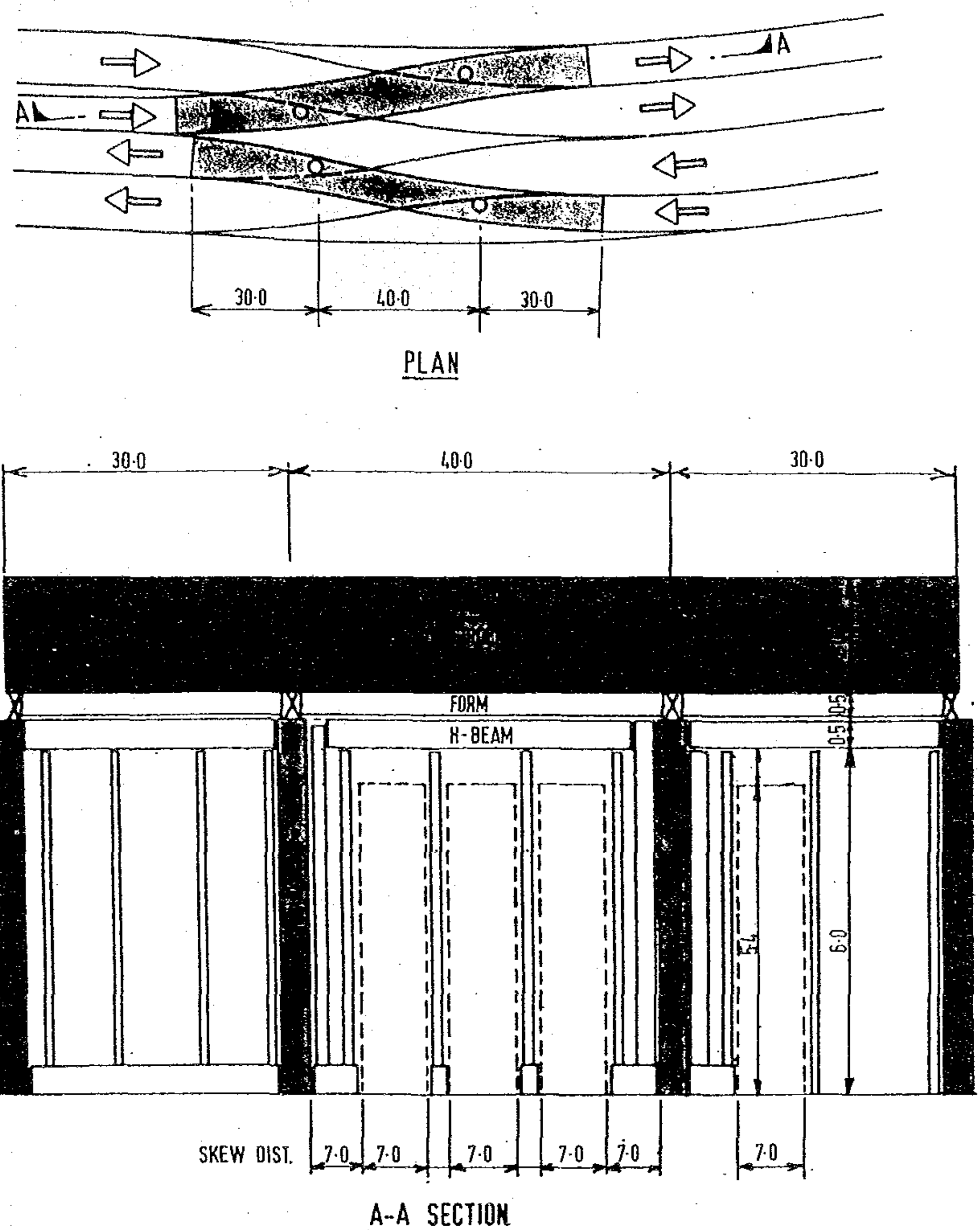
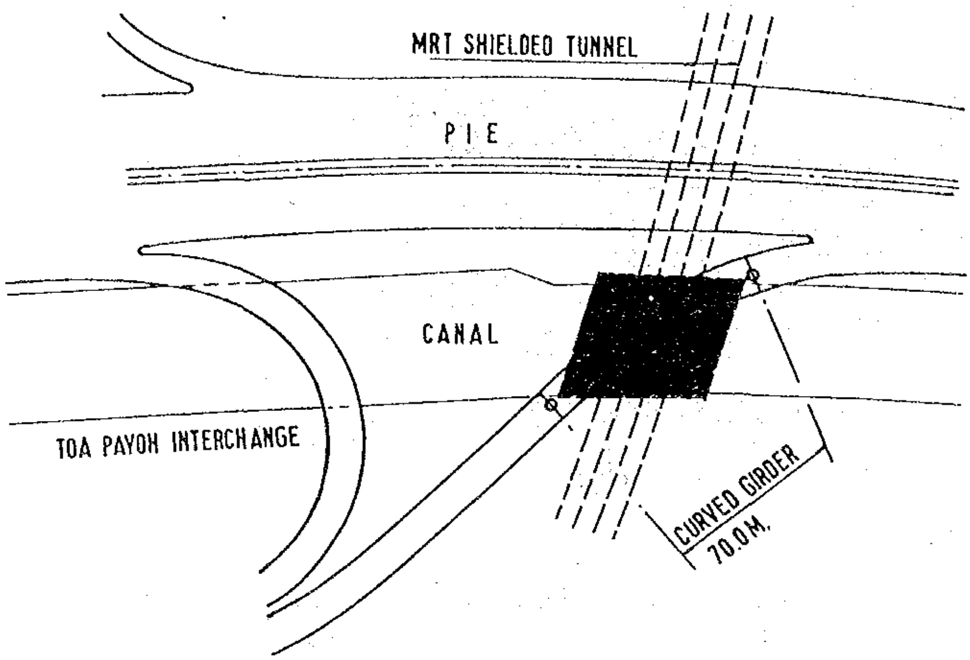
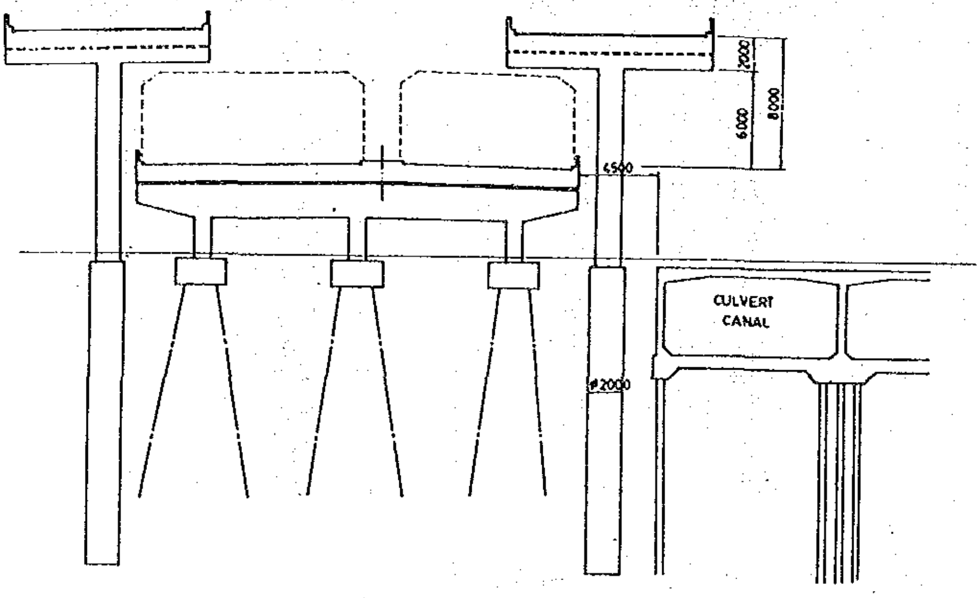


Fig. 7.10 Carriageway during construction at merging section



PIER BUILDING CLOSE TO MRT TUNNEL



PIER BUILDING CLOSE TO CANAL
AT THOMSON INTERCHANGE

Fig. 7.11 Pier building close to MRT tunnel

Fig. 7.12 Pier building close to canal at Thomson Interchange

7.2 KLE

7.2.1 Location and Type of Interchanges

For the location of interchanges in the KLE which consists of a short stretch of 3km approximately, only one interchange is proposed. This is located between KLE/ECP and KLE/PIE so as to have an appropriate distance of interval ranging 1.5km to 2.5km.

The interchange location is recommended such as to connect KLE to Nicoll Highway for convenience in commuting to Kallang Park and National Stadium. According to the traffic volume forecast in year 2010, that using the KLE/Nicoll Highway IC is forecasted up to 7,000 to 10,000 PCU/hour including in-flow and out-flow with high serviceability.

Although an interchange is desired in full service, a partial service type is adopted at KLE/Nicoll Highway IC for the following reasons;

- Land acquisition for interchange is difficult because the site is surrounded by Kallang Park and residences.
- Locating an interchange at such existing intersections as with Nicoll Highway and Mountbatten Rd. is desirable, however locating interchanges in full service close to existing intersections is *difficult due to restrictions of land acquisition.*

KLE/Nicoll Highway IC is to connect Nicoll Highway so as to serve the city bound traffic and to connect Mountbatten Rd. for service to Kallang Park bound traffic. These connections will provide sufficient service for the traffic on PIE and PYE.

The above type of interchange is recommended in the alternative as evaluated in Table 7.2 based on the aspects of expressway structure and economy.

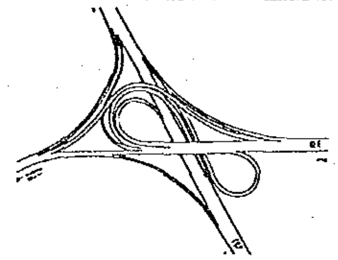
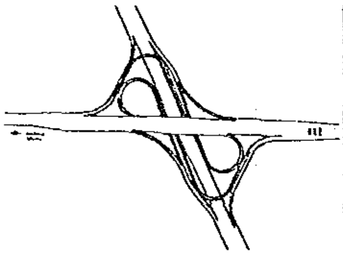
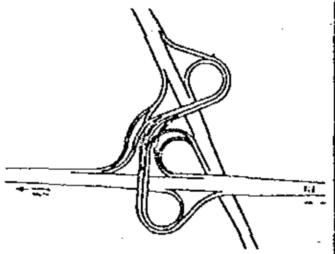
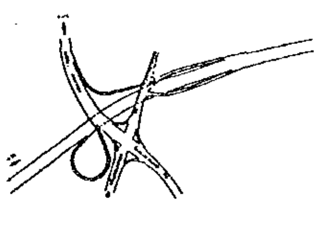
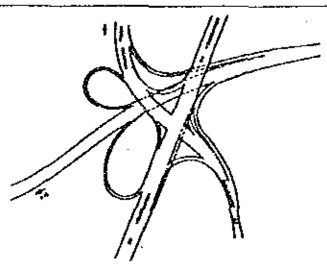
7.2.2 Route Alignment

Although KLE is a new route to be constructed, there is already a development restriction imposed at the interval between Mountbatten Rd. and Sims AV.. Besides, the span length of MRT viaduct was determined with a crossing of KLE in mind. All these facts indicate that the route alignment for this interval has been almost fixed as shown in Fig. 7.13.

Route I proposed passing across ECP and Geylang River through flyover and passing underground through Kallang Park. In the case of passing underground of *Kallang Park, since the distance between Geylang River* and Kallang Park is short, the alignment should take a detouring course in order to ensure a longitudinal grade for Designed Speed of 80km/h. The minimum radius for horizontal curve is taken as 400m and the maximum gradient is 4%.

Route II proposed passing through ECP, Geylang River and Kallang Park by tunnel. As almost the whole region is underground, Kallang Bowl becomes the control point and the horizontal alignment is upgraded and the safety increases. As for vertical alignment, consideration for the tunneling route, traffic safety and traffic capacity, the maximum available gradient is 3%. Besides, where an interchange is planned

Table 7.2 Comparison table for selecting type of interchange(KLE)

Name of Interchange	Alternative	Sketch	Description	Geometry			Economy			Evaluation
				Location	Design Speed	Horizontal Alignment	Land Acq.	Const. Easiness	Const. Cost	
KLE / ECP	Ⓐ		Modified trumpet in PWD plan mainly serves KLE-ECP,no service from Marina South to Changi bound on ECP	○	○	○	△	○	○	◎
	Ⓑ		Modified clover mainly serves to KLE-Marina South, short weaving distance from Fort Rd. Flyover causes traffic friction.	△	○	○	○	○	○	-
	Ⓒ		Solution to B above by double trumpet with alignment comp-licated.	○	○	△	△	○	○	-
KLE / Nicoll Highwa y	Ⓐ		Modified PWD plan to connect KLE bound for PIE with Nicoll bound for City,other wise connect Mount-Batten Rd. at closer to IntrSctns. of Nicoll & Mt. Bttn causes traffic friction.	○	○	○	○	○	○	◎
	Ⓑ		Solved A above,traffic service from KLE to Nicoll give stop at IntrSctns. of Nicoll & MountBatten Rd.	○	○	○	×	△	×	-

Note: ○ ; Good, Cheap, Less
△ ; Normal
× ; Bad, Expensive, More
◎ ; Recommendable

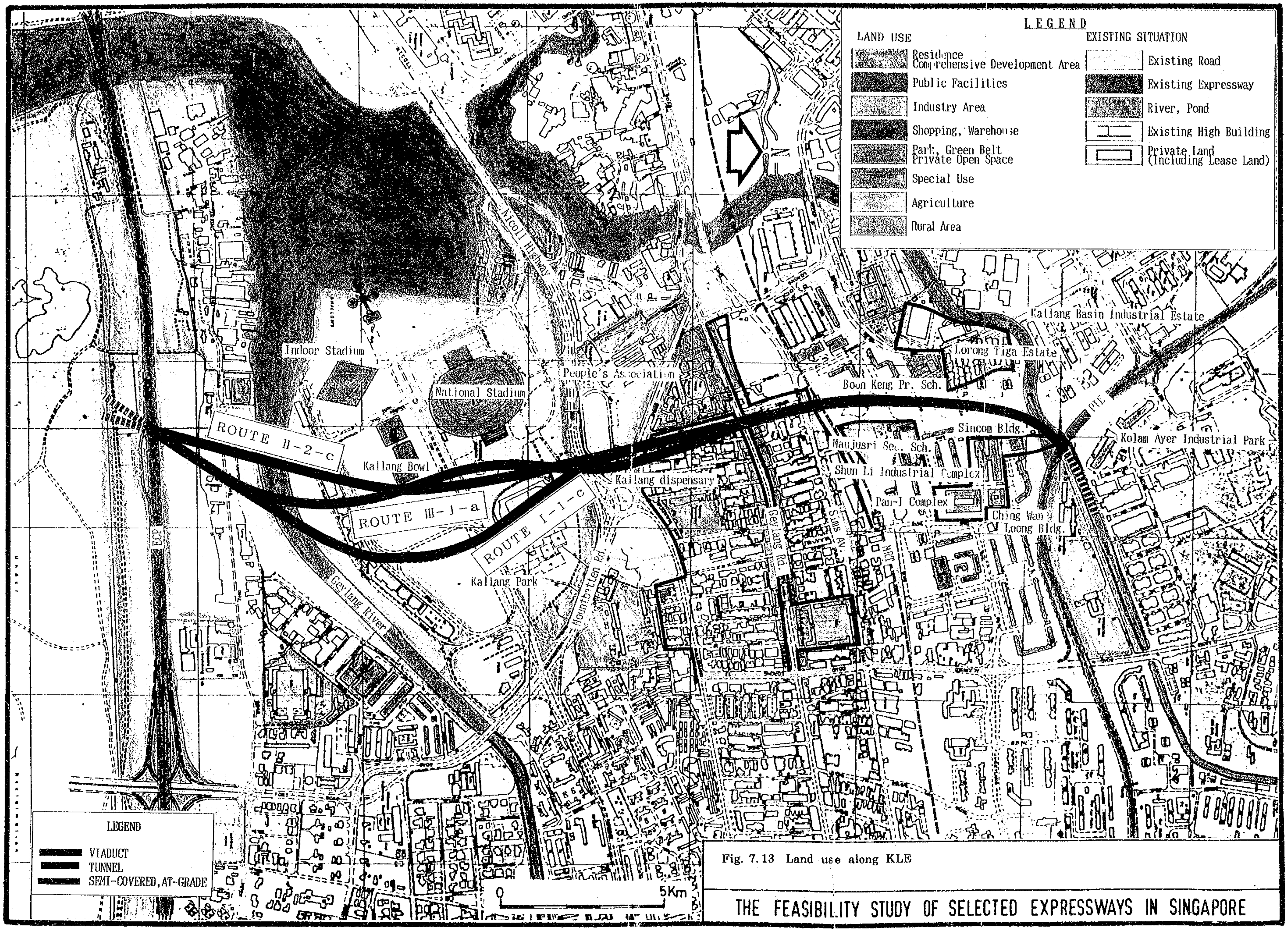


Fig. 7.13 Land use along KLE

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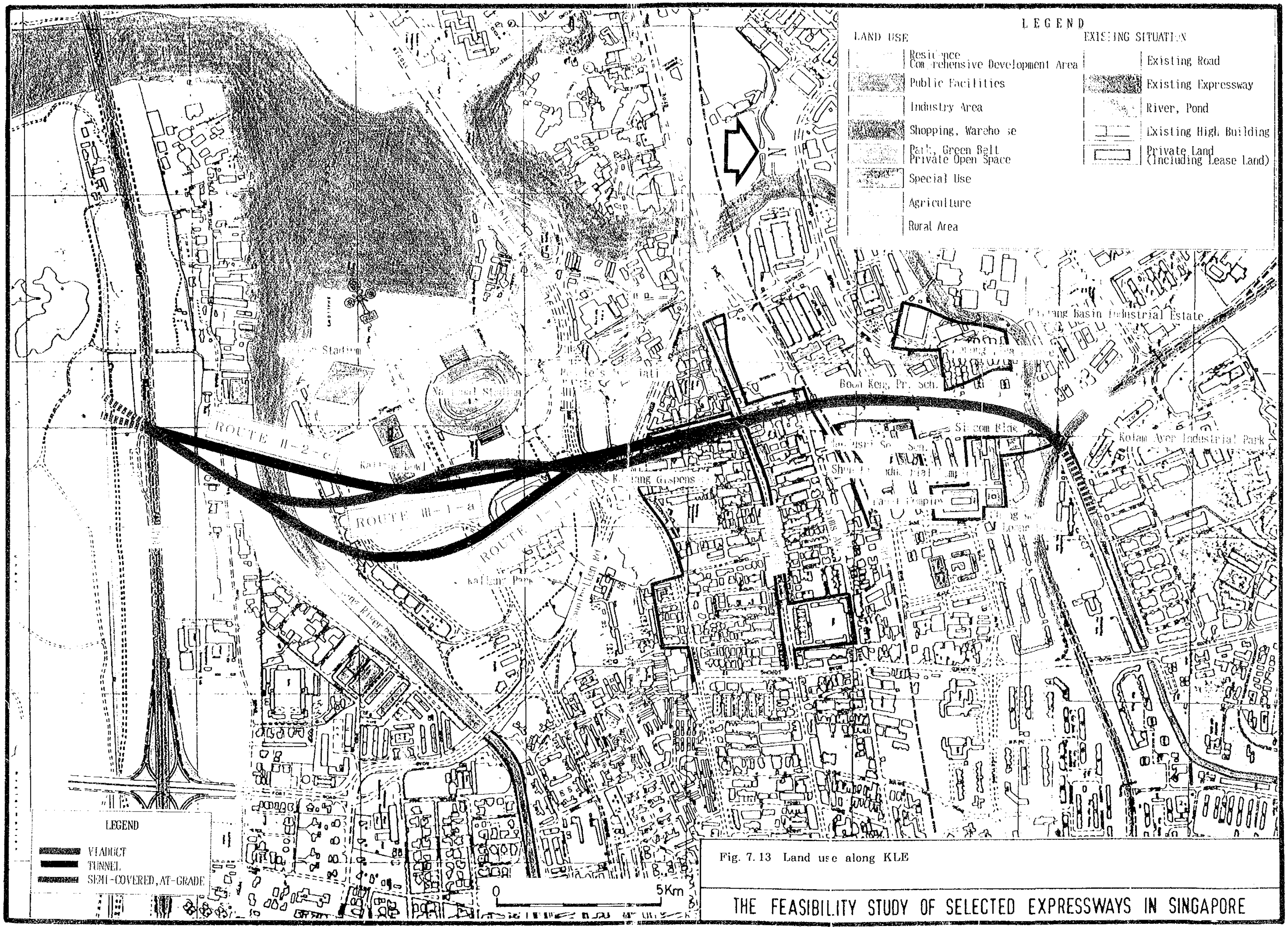

Fig. 7.13 Land use along KLE

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around Nicoll Highway, the whole route will have a radius of 1,200m.

Route III is an alignment plan for a viaduct all through the stretch from KLE/ ECP IC to KLE/PYE/PIE IC. Control points are the fields of Kallang Park as it is useless due to division by viaduct course and the Community Centre Ground. Alignment through the car park is planned to be a straight line for convenience. Minimum radius for horizontal curve is applied as 400m.

7.2.3 Structure Planning

1) Structural factors effective to route profiling

Vertical clearance for crossing routes is specified in Fig. 7.14 for the viaduct section and in Fig. 7.15 for the underground section.

Structural form is selected according to the elevation difference between proposed profile and ground profile. Structural forms are classified into 5 types and assigned to applicable heights or depths as shown in Table 7.3.

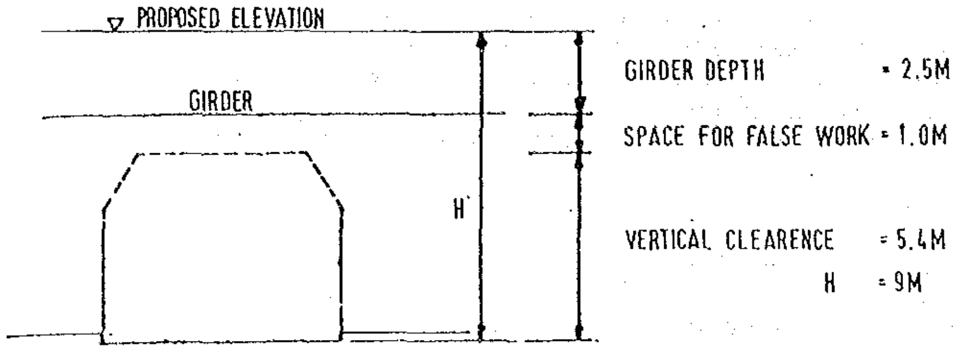
Table 7.3 Structural form selection

Structural Form	Elevation Difference
Flyover or Viaduct	2m < H
Retaining Wall or embankment	0m < H < 2m
Depressed or Trough or Cut	-7m < H < 0m
Semi-covered tunnel	-9m < H < -7m
Tunnel	H < -9m

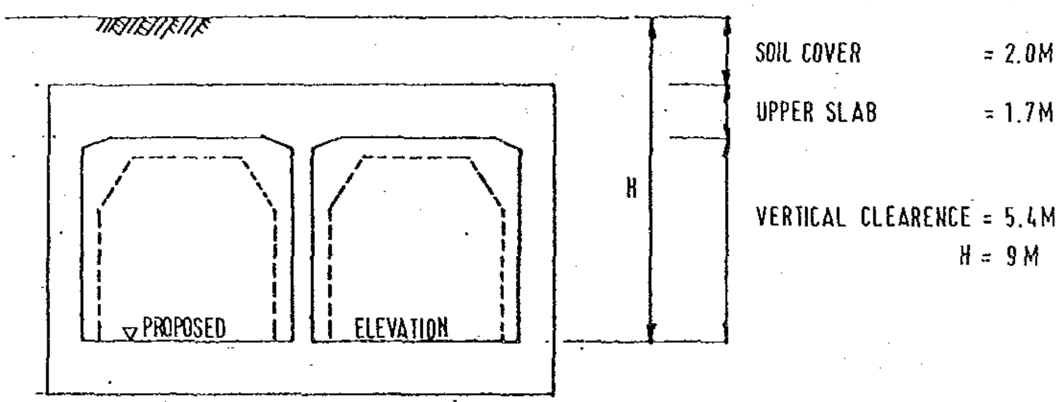
2) Crossing with river

Within the study area for KLE there are crossing points with rivers such as Geylang River in skew line and Pelton Canal at the crossing with PIE. Hydraulic data of crossing rivers is listed in Table 7.4 and cross-section of Geylang River is shown in Fig. 7.16.

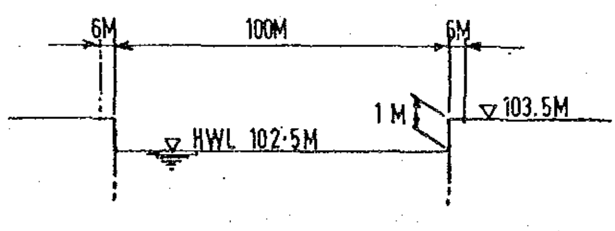
According to the hydraulic data, the possibility of scouring and afflux is likely to be low and negligible for the purpose of bridge planning. Judging from the design discharge of less than 200 m^3/sec., free board can be sufficiently set to 1 m. Free board seems afforded by the existing bank level, therefore the bridge girder should only be beyond the bank level. In case bridge pier is positioned inside the Geylang River, obstruction ratio to waterway is supposed less than 5%.
In the Alternative that the KLE takes the course of crossing over Geylang River and down in the steep slope of 4% through and beneath Kallang Park, the girder depth of bridge on the right bank to the north side affects significantly the profile of KLE.



(GIRDER DEPTH PRESUMED 1/20 TO 50M LONG SPAN)



(UPPER SLAB DEPTH PRESUMED 1/12 TO 20M LONG SPAN)



CROSS SECTION OF GEYLANG RIVER

Fig. 7.14 Girder depth presumed 1/20 to 50m long span
Fig. 7.15 Upper slab depth presumed 1/12 to 20m span
Fig. 7.16 Cross section of Geylang River

Table 7.4 Hydraulic data of rivers

	Geylang River	Pelton Canal
Design discharge	Less than 200	Less than 200
Highest Flood level	102.5m	102.5m
Stability of Stream line	Stable	Stable
Level of river bed	100 m	100 m
Top level of river bank	103 m	103 m
Soil of river bed	Muddy Clay	Concrete Invert

While a 3 span continuous girder would raise the profile so as to exceed the permissible slope on approach as shown in Fig. 7.17, a 2 span continuous girder is proposed. In order to lower the minimum slope on approach, as shown in Fig. 7.18, the continuous girders that are supported by rigid framed piers in the center of Geylang River are tapered to a lower height at both ends. The structural details will be worked out in the Phase II of the Study through discussions with PWD.

In the Alternative of crossing under Geylang River by tunnel, soil cover above tunnel below river bed is specified with a thickness of more than 3m consisting of 1m for river bed fluctuation and 2m for river maintenance space.

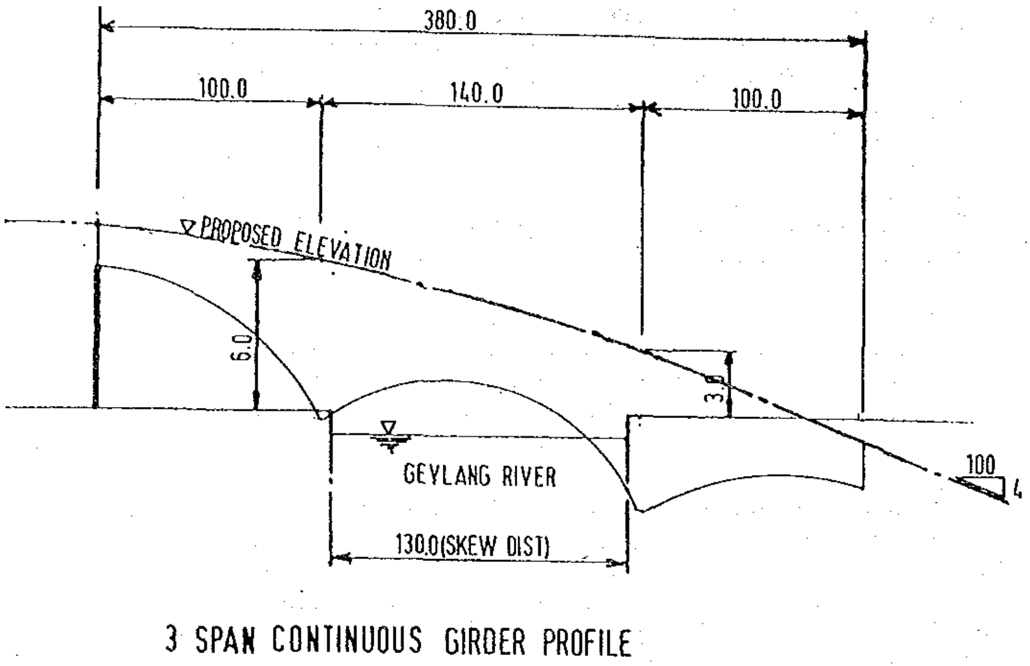
In the Alternative of a viaduct all through the route, the proposed profile is elevated to the height of 9m to 13m above the ground level to accommodate vertical clearances at the crossing with ECP, PIE and MRT viaduct. On the viewpoint of aesthetics, the elevation of 13m may have an oppressive impression below the bridge floor.

3) Semi-covered structure and tunnel

(1) Type of tunnel

Open cut method is presumed to occupy the additional area during construction as shown in Fig. 7.19. Soil profile as indicated in Appendix 7.2 consists of soft marine clay sedimented in Alluvium up to the depth of 20m approximately with its physical property as listed in Table 7.5. Geological condition described so far implies such construction methods as open cut and cover method in 2 cell type square tube if the construction space to occupy is permissible on the top ground, or shielded tunneling method in tube. However, shielded tunneling method requires 19m of outer diameter as shown in Fig. 7.20, of which scale is beyond the state of the art. For alternative formulation, open cut and cover method is recommended so as to scheme the proposed profile at a shallow depth.

(2) Type of semi-covered tunnel



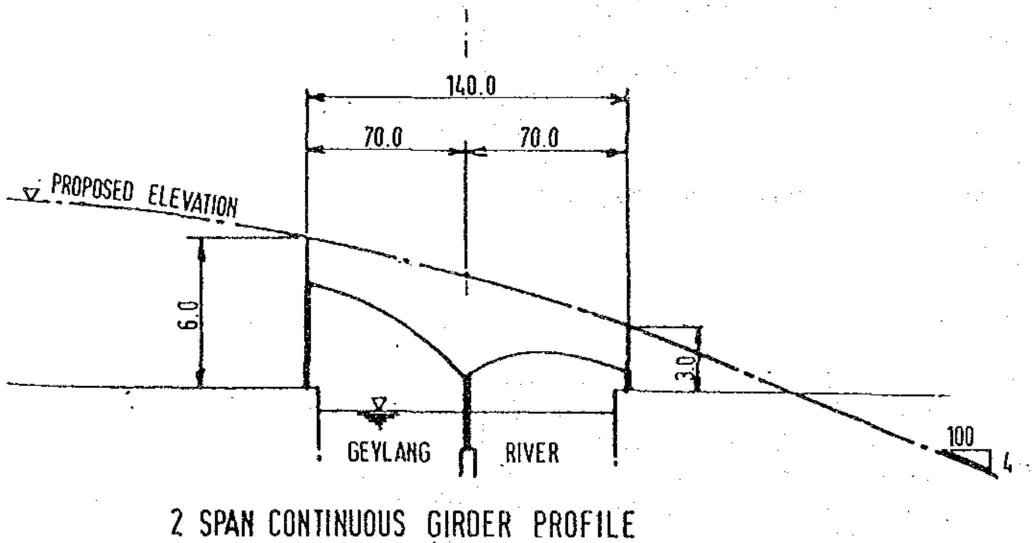


Fig. 7.17 3 span continuous girder profile

Fig. 7.18 2 span continuous girder profile

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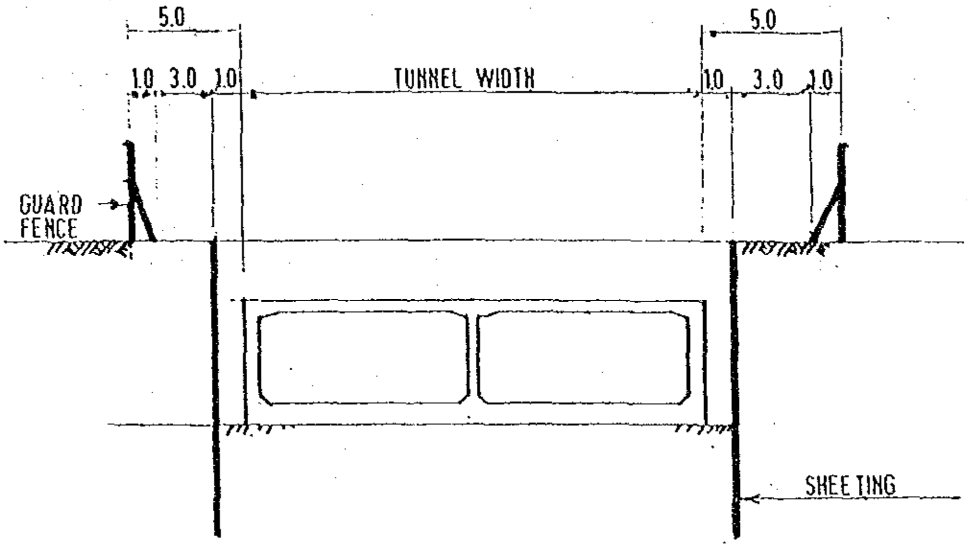
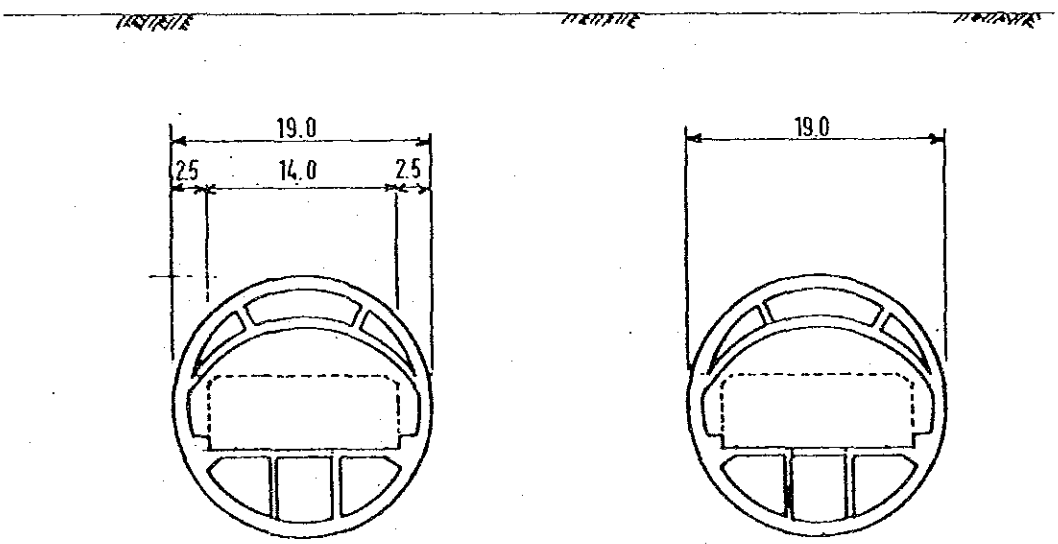


OCCUPIED AREA DURING CONSTRUCTION



SUPPOSED SHIELDED TUNNEL

Fig. 7.19 Occupied area during construction

Fig. 7.20 Supposed shielded tunnel

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Fig. 7.21 indicates the cross-section, of which horizontal clearance is determined based on the geometric regulations of KLE. Saving cost of land acquisition, semi-covered type by cantilevered slab (7m long) hangs over the depressed tunnel to carry the streets.

In case the streets cross over the tunnel, they can be carried by PC precast beam girder with a bridge span of 16m supported by piers positioned at the median of depressed KLE as shown in Fig. 7.22.

4) Viaduct

As the ground condition along the study route is soft, a heavy structure

Table 7.5 Soil property of alluvial strata

	Upper Marine Clay	Lower Marine Clay	Old Alluvium
Natural moisture (%)	60-80	50-60	Dense sand
Specific gravity	2.60-2.75	2.60-2.72	
Bulk density (tf/m3)	1.49-1.65	1.65-1.84	
Liquid limit (%)	80-95	60-80	
Plastic index (%)	50-65	35-50	
Undrained shear strength (tf/m2)	1.0-3.0	4.0-7.0	
Over consolidation ratio	1-2	1-2	
Compression coef.	0.7-1.3	0.5-1.0	
Sensitivity ratio	5-10	6-12	

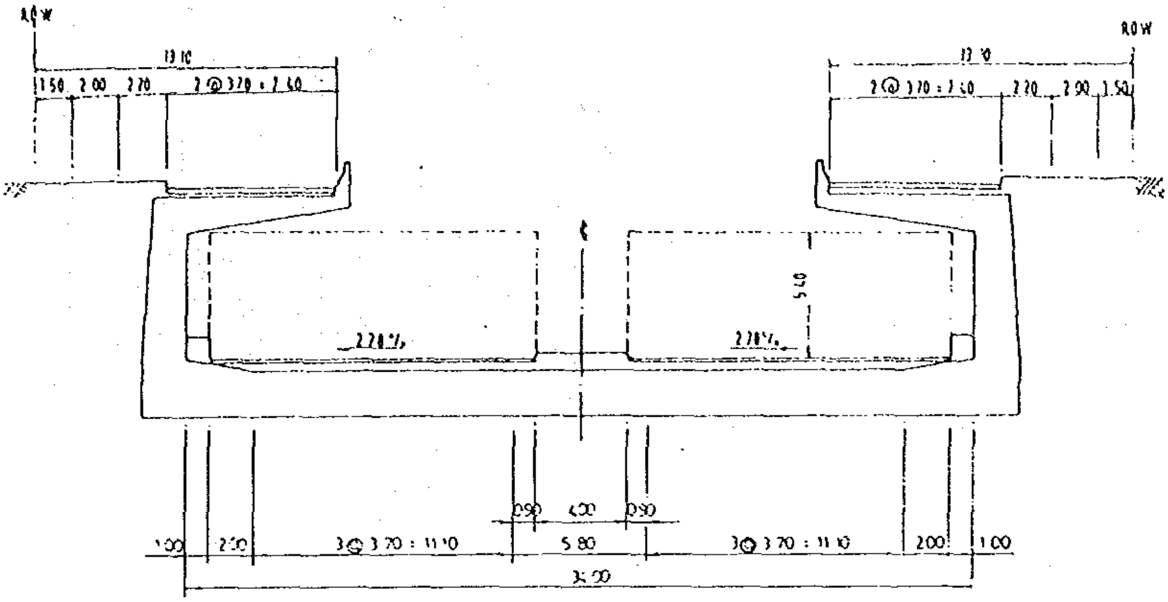
Source : Japan Association of Soil Mechanics and Foundation Engineering

is not preferred. A simple girder bridge using precast concrete beam with a 25m span is recommended.

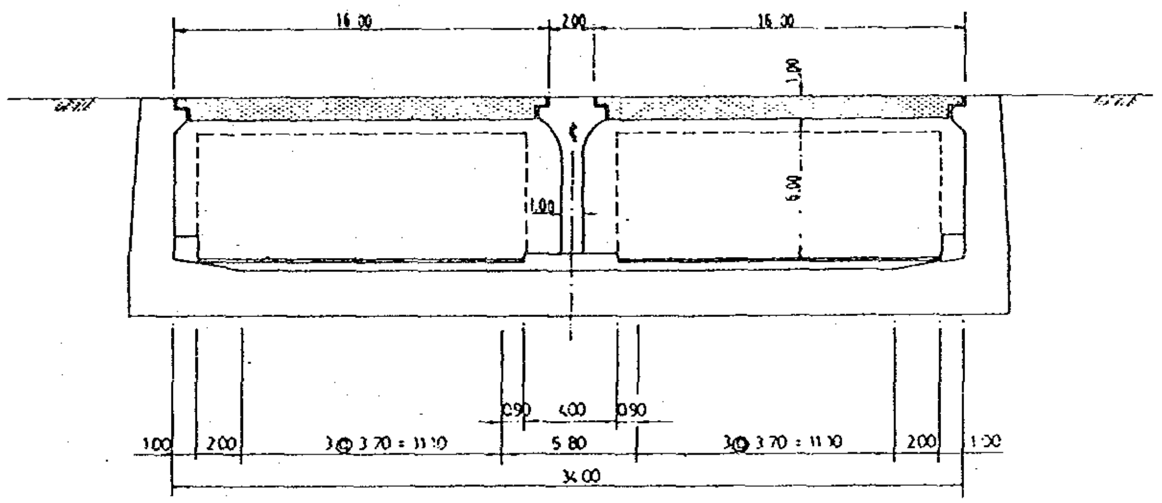
A predominant layer of soft subsoil, known as marine clay, lies above the diluvial stratum, known as Old Alluvium, outcropping at Paya Lebar. The Old Alluvium seems to have a suitable bearing capacity for structure foundations. Stratification of the Old Alluvium varies its depth at a large gradient from 20m to 40m below the ground surface. Regarding the type of foundation work, piled foundations are recommended for the base, although the excessive variation of the bearing stratum implies application of cast in place Reinforced Concrete piles or H-section steel piles. PC precast piles are recommended in the case of shallow base level. Semi-covered tunnels and tunneling structures are not furnished with pile foundations.

5) Close construction to MRT

At the location where the KLE route is under the viaduct of the MRT, a depressed trough is used between the piers of the MRT viaduct. Construction work is expected to be in the vicinity of the pier foundations of MRT as shown in Fig. 7.23. Pile foundations are necessary at this stretch of the KLE to prevent the trough weight from affecting the pier foundations of the MRT.



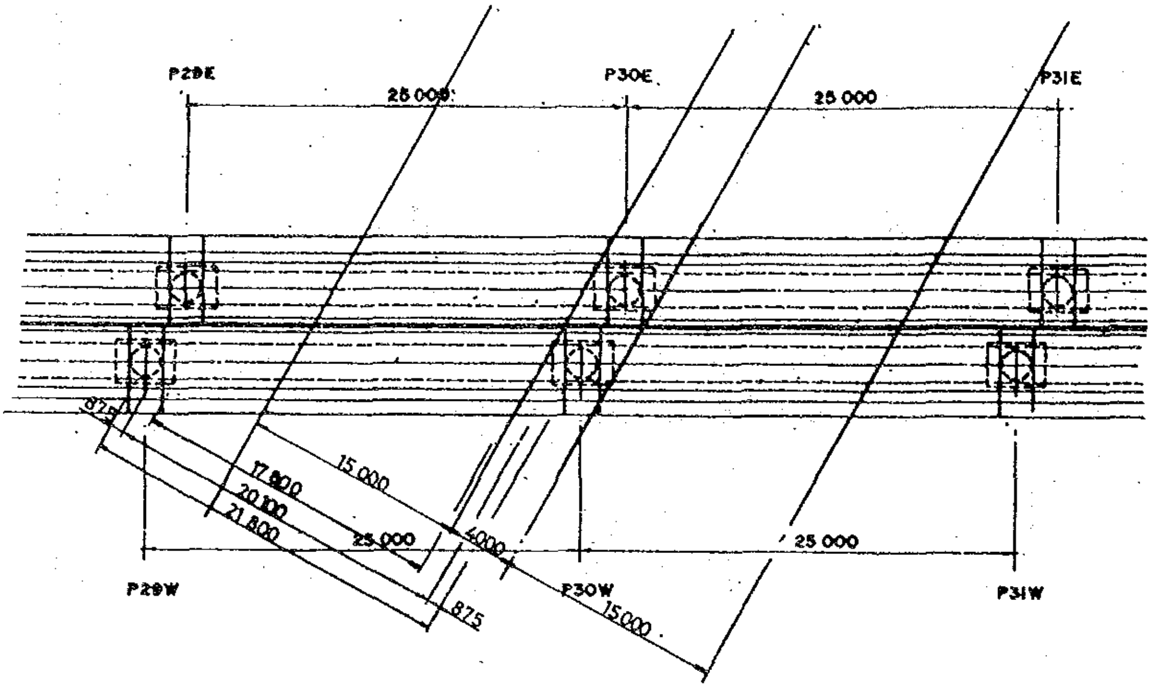
SEMI COVERED DEPRESS



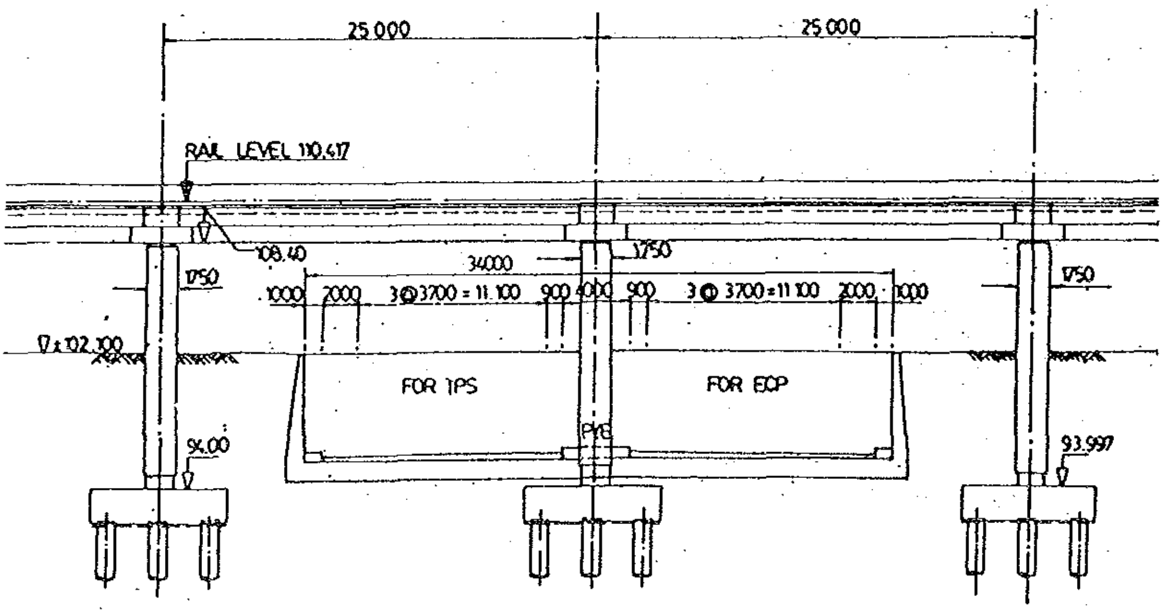
CROSSING AT SEMI-COVERED DEPRESS

Fig. 7.21 Semi-covered depressed

Fig. 7.22 Crossing at semi-covered depressed



PLAN



SECTION

Fig. 7.23 Close construction to MRT

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

7.3 PYE

7.3.1 Location and Type of Interchanges

All the main roads that join to PYE are shown below. Out of these roads, connections to PIE and TPE are of interchanges between expressways. Besides, the Route has an important role of directing all the traffic generated at Punggol North Road to Marina South area. These 3 interchanges must be included in our planning. Since Aljunied Rd. is very near to the interchange with PIE, access service is not required.

Route I	PIE, Aljunied Road, Paya Lebar Road, Airport Road, Tampines Road, Punggol North Road, TPE.
Route II	PIE, Aljunied Road, Paya Lebar Road, Hougang Avenue 3, Defu Avenue 1, Tampines Road, Punggol North Road, TPE.
Route III	PIE, Aljunied Road, Paya Lebar Road, Hougang Avenue 3, Tampines Road, Punggol North Road, TPE.

According to traffic volume forecast, none of the interchange need to be removed as every interchange has to handle a certain amount of traffic.

Considering the accessibility of normal road with each interchange, it is concluded that the access method shown in Table 7.6 is recommended.

In general, the type of interchange is classified into three-leg type and four-leg type, by its configuration of intersection, according to the service level of intersecting roads, traffic volume and restriction to ROW. Based on the characteristics, alternatives are formed considering the differences among interchange types and evaluation of expressway structures and economy, as summarised in Table 7.7.

Based on the results of the above discussion, the location of interchanges is decided to be I-1, II-2 and III-2.

7.3.2 Route Alignment

PYE can be divided into 3 main intervals as PYE/PIE - PYE/Paya Lebar Rd. - PYE/Tampines Rd. - PYE/TPE. The stretch between PYE/Paya Lebar Rd. and PYE/Tampines Rd. has 3 alternative plans as shown in Fig. 7.24.

In the stretch from KLE/PYE/PIE IC to PYE/Paya Lebar Rd., route alignment is roughly on the Pelton Canal as the survey corridor is restricted to the belt of the canal course and as both sides of the canal are occupied by tall residential buildings. The route is aligned such that it is partially on the west side of the canal. This is to avoid tall condominiums and this will enable the design speed of 80 km/H to be kept.

As described before there are 3 Alternative Routes for the stretch from PYE/Paya Lebar Rd. to PYE/Tampines Rd.. Route I takes the course along and above the Airport Rd. and underneath the Air Base as far as Tampines Rd.. Control points on this route are an industrial estate which is

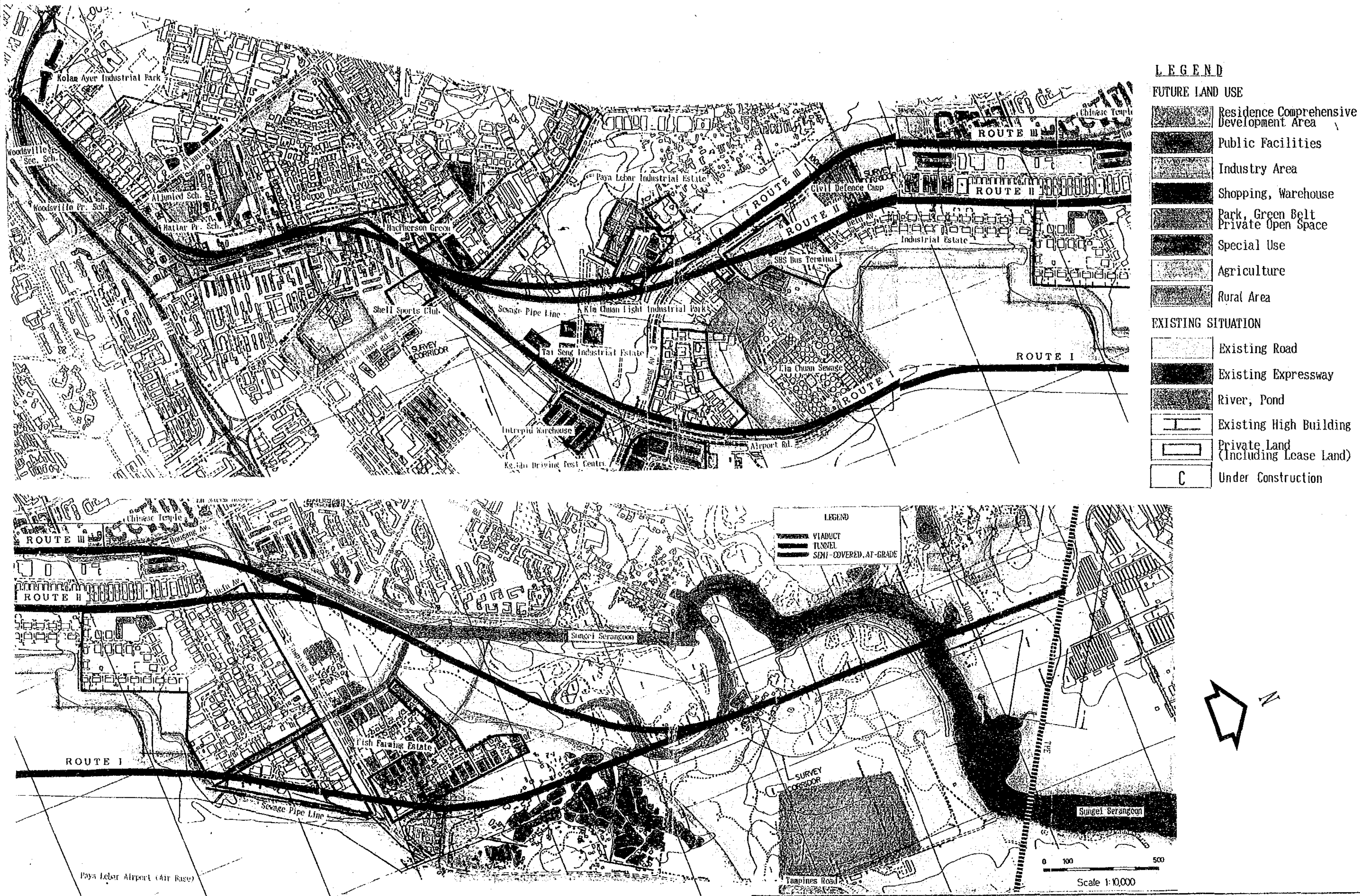


Fig. 7.24 Future land use and control point along PYE

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

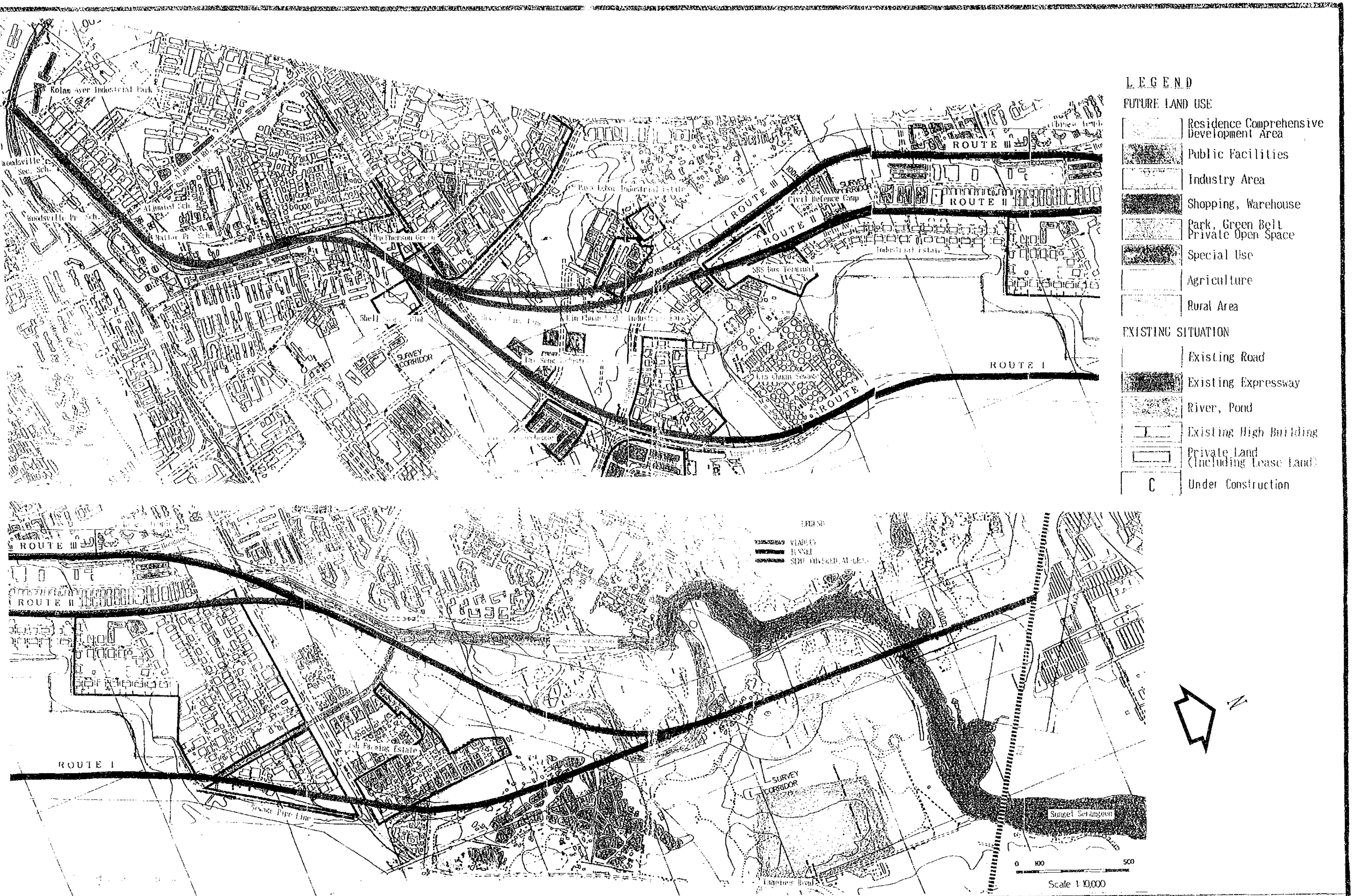


Fig. 7.24 Future land use and control point along PYE

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Table 7.6 Access method on each IC (Route I)

Name of Interchange	PYE/ KLE/ PIE	PYE/ PAYA LEBAR RD	PYE/ AIR- PORT RD.	PYE/ TAMP INES RD	PYE/ PUNG GOL NT.	PYE/ TPE
Full service		O		O	O	O
Partial service	O		O			

(Route II)

Name of Interchange	PYE/ KLE/ PIE	PYE/ PAYA LEBAR RD	PYE/ DEFU NT. RD.	PYE/ DEFU CT. RD	PYE/ DEFU ST. NT.	PYE/ PUNG GOL NT.	PYE/ TPE
Full service		O				O	O
Partial Service	O		O	O	O		

(Route III)

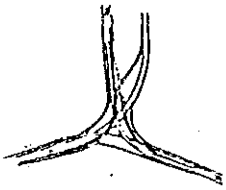
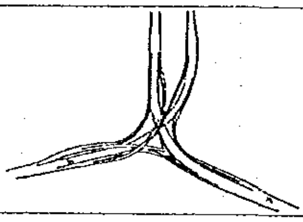
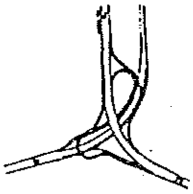
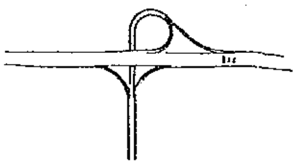
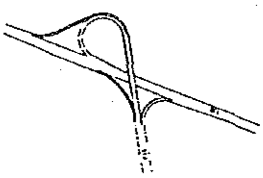
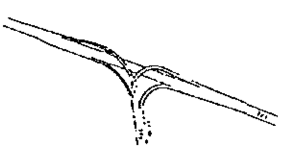
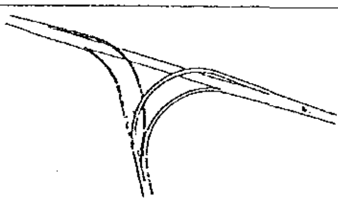
Name of Interchange	PYE/ KLE/ PIE	PYE/ PAYA LEBAR RD	PYE/ HOUG ANG NT.	PYE/ HOUG ANG CT.	PYE/ HOUG ANG ST.	PYE/ PUNG GOL NT.	PYE/ TPE
Full service		O				O	O
Partial Service	O		O	O	O		

presently under construction on the north side of Airport Road, a warehouse and a sewage disposal station on the south, and sewage pipe lines to the north of the Air Base. Control point to vertical alignment is the Airport Road at the entrances of the tunnel. A gradient of 4% at maximum is applied .

Route II is to take the course on Defu Av. I with such control points as an industrial estate (the same one in the Route I) and other industrial estates both on Hougang Av. III and on Defu Av. I. That estate on Defu Av. I is on government owned land. Therefore, after the lease expires, HDB will retain the land and horizontal alignment can have a larger radius curve to ensure high speed performance. In vertical alignment with a control point such as Kim Chuan Rd. to all alternatives, i.e. viaduct, at-grade and semi-underground, the maximum gradient is set to 3%.

Route III has control points such as industrial estates (the same one as in Route I and II) and tall housing buildings on the north side of Hougang Av. III. Vertical alignment has control points such as Kim Chuan Rd. as in the underground plan and canal at the upstream of

Table 7.7 (1) Comparison table for selecting type of interchange (PYE common)

Name of Interchange	Alternative	Sketch	Description	Geometry			Economy			Evaluation
				Location	Design Speed	Horizontal Alignment	Land Acq.	Const. Easiness	Const. Cost	
PYE / KLE / PIE	Ⓐ		Modified PWD plan directly connect KLE with PIE Changi bound, ramp from PYE to PIE Jurong bound need 3 tiers viaduct	○	○	△	○	△	△	–
	Ⓑ		Main service KLE to PYE all right turning connect quasi-directly, 2 ramps: PYE to PIE Jurong bound & KLE to PIE Changi bound need 3 tiers viaduct.	○	○	○	○	△	△	◎
	Ⓒ		Modified solution to avoid 3 tiers.	○	△	△	△	○	○	–
PYE / Punggo l Nt. Rd.	Ⓐ		Reversed trumpet to serve full traffic btw. PYE bound for PIE & Punggol Nt. Rd	○	○	○	○	○	○	◎
PYE / TPE	Ⓐ		Typical trumpet-shaped interchange.	○	△	△	△	○	○	–
	Ⓑ		Y-shaped interchange in quasi-direct-connection with 3 tiers viaduct, but smaller ROW than Ⓐ above.	○	△	△	○	△	△	–
	Ⓒ		Y-shaped interchange in quasi-direct-connection without 3 tiers, render best speed performance.	○	○	○	△	○	△	◎

Note: ○ ; Good, Cheap, Less
△ ; Normal
× ; Bad, Expensive, More
◎ ; Recommendable

Table 7.7 (2) Comparison table for selecting type of interchange (PYE Route-I)

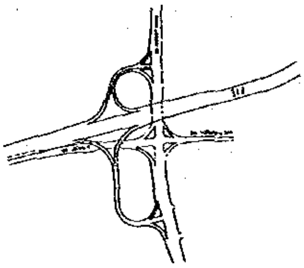
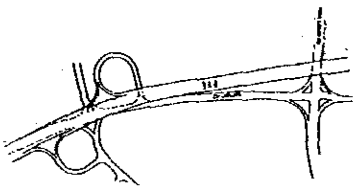
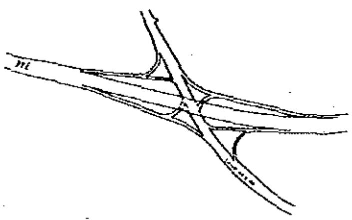
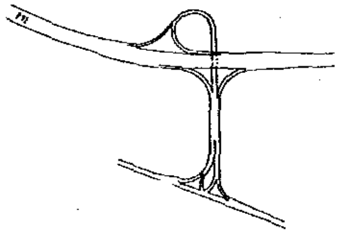
Name of Interchange	Alternative	Sketch	Description	Geometry			Economy			Evaluation
				Location	Design Speed	Horizontal Alignment	Land Acq.	Const. Easiness	Const. Cost	
PYE / Paya Lebar Rd.	Ⓐ		Incomplete clover-leaf due to passing near the Intrsctn of PayaLebar Rd. & Airport Rd.,3 crossings repeat cause traffic friction.	△	○	△	○	△	○	◎
	Ⓑ		Solution to Ⓐ above by inserting incomplete clover Intr. on Airport Rd. btw.Paya Lebar Rd. & Hougang Ave.III, cause traffic concentration to Airport Rd. of high speed vehicle.	△	○	△	△	○	○	–
PYE / Airport Rd.	Ⓐ		Half diamond type to connect PYE traffic bound for TPE with Airport Rd.	△	○	△	○	○	○	◎
PYE / Tampines Rd.	Ⓐ		Diamond type to connect at crossing to Tampines Rd.	○	○	○	○	○	○	◎
	Ⓑ		Modified Ⓐ above to connect at northward to Tampines Rd. by trumpet interchange, closer to Intrchng to PYE/Punggol Nt.Rd	△	○	△	△	△	△	–

Table 7.7 (3)　　Comparison table for selecting type of interchange (PYE Route-II)

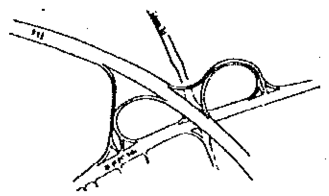
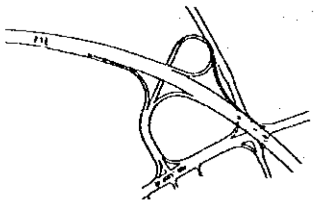
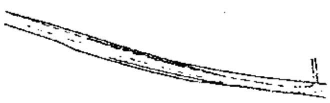
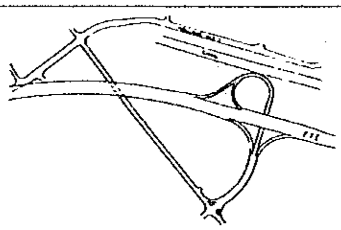
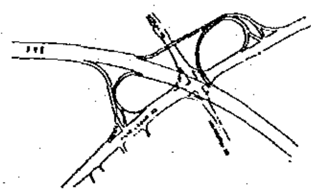
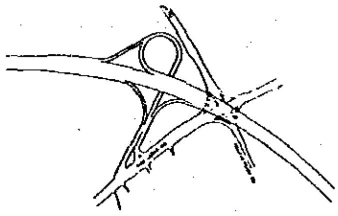
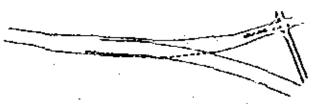
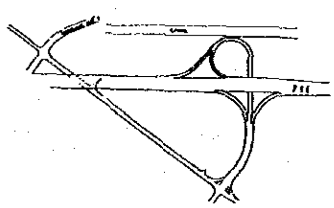
Name of Interchange	Alternative	Sketch	Description	Geometry: Location	Geometry: Design Speed	Geometry: Horizontal Alignment	Economy: Land Acq.	Economy: Const. Easiness	Economy: Const. Cost	Evaluation
PYE / Paya Lebar Rd.	Ⓐ		Incomplete clover-leaf due to passing near the Intrsctn of PayaLebar Rd. & Airport Rd.,3 crossings repeat cause traffic friction.	△	○	△	○	△	△	–
	Ⓑ		Solution Ⓐ above to connect PayaLebar Rd. by reverse trumpet,added with one more at-grade intersection.	○	○	○	△	○	○	◎
PYE / Defu South	Ⓐ		Plan to assure convenience of Defu Industry by connecting PYE bound for PIE to Defu Ave.I by half-diamond.	△	○	○	○	○	○	◎
PYE / Defu North	Ⓐ		Plan to connect traffic on PYE bound for PIE & Hougang north area to Defu Ave. I by half-diamond.	○	○	○	○	○	○	◎
PYE / Hougang	Ⓐ		Plan to connect traffic on PYE bound for TPE & Hougang North area to Hougang Ave. 7,but need bridge over Serangoon Canal, in full service combined with PYE/Defu North.	○	○	○	○	○	△	◎
	Ⓑ		Trumpet shaped I/C in full service to connect Tampines Rd.	○	○	△	×	△	△	–

Table 7.7 (4) Comparison table for selecting type of interchange (PYE Route-III)

Name of Interchange	Alternative	Sketch	Description	Geometry: Location	Geometry: Design Speed	Geometry: Horizontal Alignment	Economy: Land Acq.	Economy: Const. Easiness	Economy: Const. Cost	Evaluation
PYE / Paya Lebar Rd.	Ⓐ		Incomplete clover-leaf due to passing near the Intrsctn of PayaLebar Rd. & Airport Rd.,3 crossings repeat cause traffic friction.	△	○	△	○	△	△	–
	Ⓑ		Typical trumpet I/C to solve problematic Ⓐ above by connecting to PayaLebar Rd. added with one at-grade intersection.	○	○	○	△	○	○	◎
PYE / Hougang South	Ⓐ		Half-diamond type to assure convenience of Hougang Nt. by PYE traffic bound for PIE to Hougang Ave.3.	△	○	○	○	○	○	◎
PYE / Hougang Central	Ⓐ		Half-diamond type to connect traffic on PYE bound for PIE & Hougang Nt. to Hougang Ave.3.	○	○	○	○	○	○	◎
PYE / Hougang North	Ⓐ		Half-diamond type to connect traffic on PYE bound for TPE & Hougang Nt. to Hougang Ave. 7, need bridge over Serangoon Canal in full service combined with PYE/ Hougang Central.	○	○	○	○	○	△	◎
	Ⓑ		Trumpet in full service to connect Tampines Rd.	○	○	△	×	△	△	–

Serangoon River and a maximum of 3% longitudinal gradient is applied.

The stretch from PYE/Tampines IC to PYE/TPE IC takes a course in the area where future new-towns are planned. Although there are few control points in this selected route, Route I is aligned horizontally on terrain predominated by a winding river and crossing point of the bridge is at Serangoon River. Route II and III are aligned parallel to the Serangoon River and towards the northeast direction to join Route I so as to avoid separating land into useless divisions.

7.3.3 Structure Planning

On the structure planning of PYE, multifarious topographical situations should be taken into consideration. The type of structure to be selected for the PYE will depend on the terrain locality along its route.

Route profile for the viaduct can be of the same form of structure as KLE, in good proximity. Pier locating inside the waterway of Pelton Canal yields no problem on the river management. For aesthetic reasons, it is not preferred to build a portal pier with columns on both banks.

Route options proposed for the northern corridor far from Paya Lebar Rd. consists of 3 courses. Route I aliasing with the Air Base Route is more suitable to have grade separation on Airport Rd. and a tunnel under the Air Base for military security reasons. Transition section from grade separation by viaduct to underground tunnel requires the approach embankment to be retained by walls and a trough approach when entering the tunnel. Profile or depth of tunneling section under the Air Base depends on the tunneling method.

Shielded tunneling method has advantages such as occupation of additional land for construction use on the ground above it and is not required and there is little settlement of ground after the construction. However it has disadvantages such as the cost of machine applied is high and boring diameter has a limit of 13.5m. As shown in Fig. 7.20, required diameter for the proposed PYE carriageway is 19m wide which is beyond the state of the art. While NATM method is a feasible alternative, sufficient geological information is very crucial to the selection, cost estimation and settlement forecasting. At this stage of the Study, open cut and cover method by square section in two cells is presumed, as suggested by the PWD counterpart. The profile of tunnel section is proposed according to the elevation with a minimum soil cover on the Air base area.

On the approaching section towards the tunnel beside the Air Base, depressed type is preferred in order to avoid the Air Base.

The Northern area, apart from the Air base course, was formerly a fish farm and an unidentified area. It is now reformed to tablelands for dumping waste soil. According to our field inspection, filled soil is observed to be of a subgrade material which is good for expressway pavements.

In the Route of Alternative II and III, the route of the viaduct stretches from the common section to north of Airport Rd., then passes Defu Av. 1, which has structural alternatives, and passes Hougang Av. 3, which has 2 structural alternatives, respectively. Residential areas in

Hougang as well as industrial estates in Defu area have sufficient roadside belts for various options of structural form and construction methods.

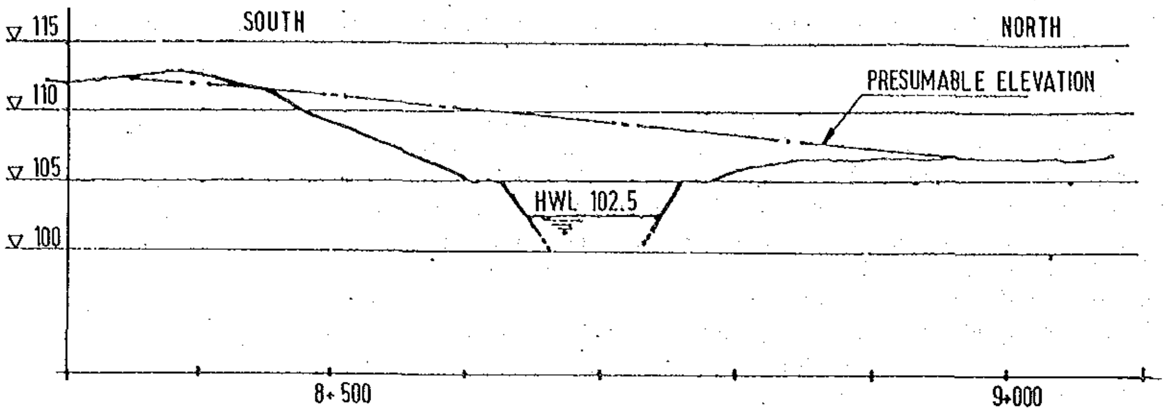
After the above two routes cross Tampines Rd., they are extended towards the northern area, where it is a back marsh area as shown in a topographical map. The right bank of Serangoon River is now under reclamation by waste soil and reformed to the tablelands. Filled layer is presumed several meters deep, and underlain by peat layer and alluvial strata. In case of viaduct type, deep foundations are recommended. Filled surface soil is observed to have a sound subgrade which is good for the pavement of a ground level expressway. However, there is insufficient data for subgrade to affirm the stability of embankment.

All the proposed Alternatives will cross over the Serangoon River near the north end of the survey corridor.

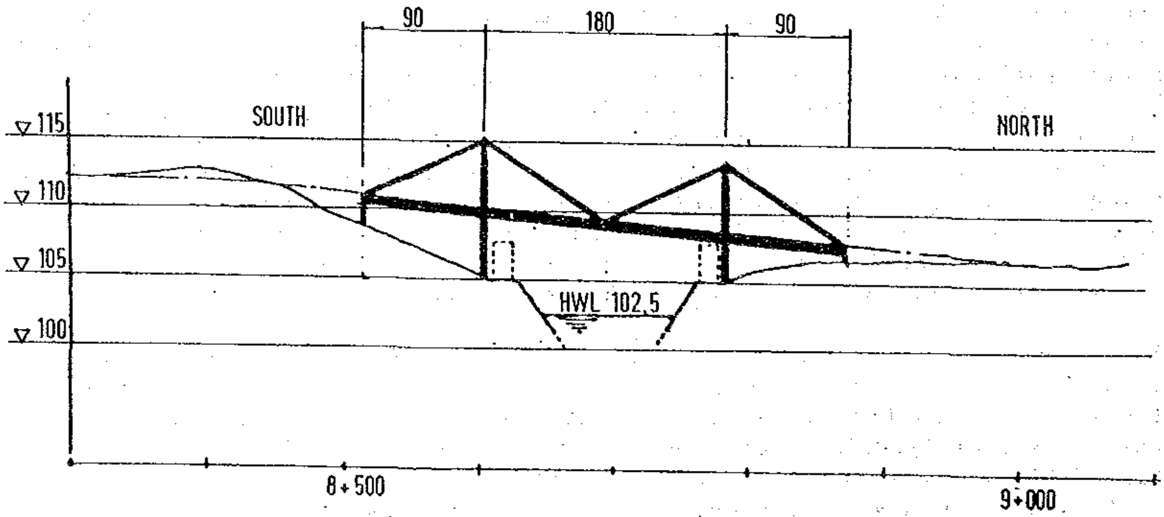
The Serangoon River has been under revetment works and dredging of the river bed is only possible when the condition of waterway is stable. Former back marsh area on the right bank is changing its profile because of the continuous dumping of waste. As shown in Fig. 7.25, terrain profile approaching the bridge will have an influence on the selection of bridge type. Slightly unknown is the stability of waterway at the bridge crossing site which has a small scale of flood discharge. However, this poses no problem to the above alternatives. For bridge type, a 3-span continuous bridge with cast in place PC box girder by cantilever method over the waterway is recommended.

In cases where the vertical clearance raises the bottom level of the girder for maintenance purposes or where the vertical alignment lowers the profile, or where aesthetical requirements need deep clearance, a thinner girder type is recommended for the study alternative as shown in Fig. 7.26. In the case where structural conditions take priority, a flat profile of proposed elevation is acceptable as shown in Fig. 7.27. The selection described so far will be conducted after collecting sufficient data in Phase II of the Study. Approaching structure for the Serangoon River bridge crossing is recommendable by applying viaduct type to avoid embankment.

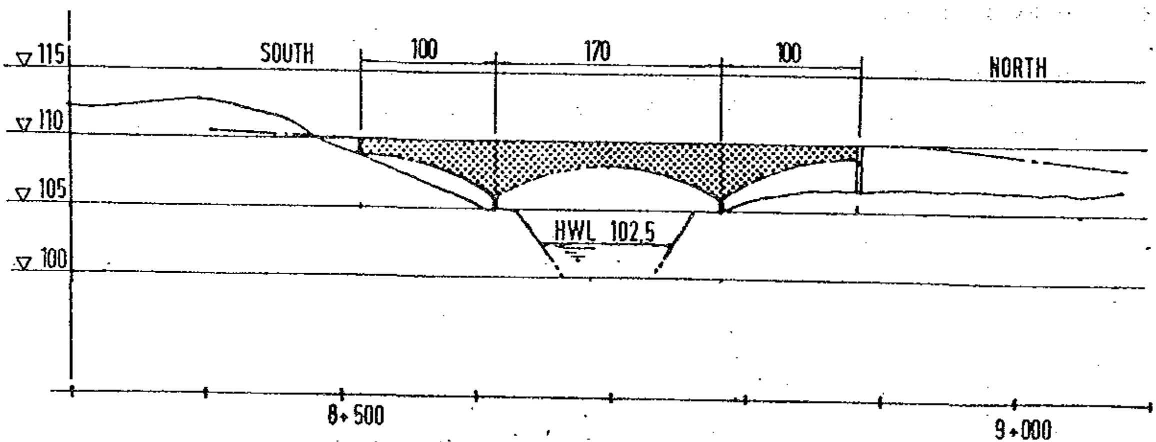
After passing over the Serangoon River by the bridge the Route takes the course on the ground level expressway until the interchange to Tampines Expressway under plan.



TERRAIN PROFILE AT CROSSING ON SERANGOON RIVER



PROPOSED PROFILE FOR SERANGOON RIVER CROSSING



PROPOSED PROFILE FOR SERANGOON RIVER CROSSING

Fig. 7.25 Terrain profile at crossing on Serangoon River
Fig. 7.26 Proposed profile for Serangoon River (1)
Fig. 7.27 Proposed profile for Serangoon River (2)

CHAPTER 8

EVALUATION OF ALTERNATIVES

CHAPTER 8 EVALUATION OF ALTERNATIVES

In this chapter, all the alternatives established for each expressway are assessed based on whether the functions of an expressway (high speed, safety and comfort) are fulfilled. The balance with natural conditions and social conditions in the region which the route passed through is also considered, and whether there is a balance between investment and effect. The alternatives that are to be given priority after this assessment will be the target for phase II study to select the best route. The procedure is shown in Fig. 8.1.

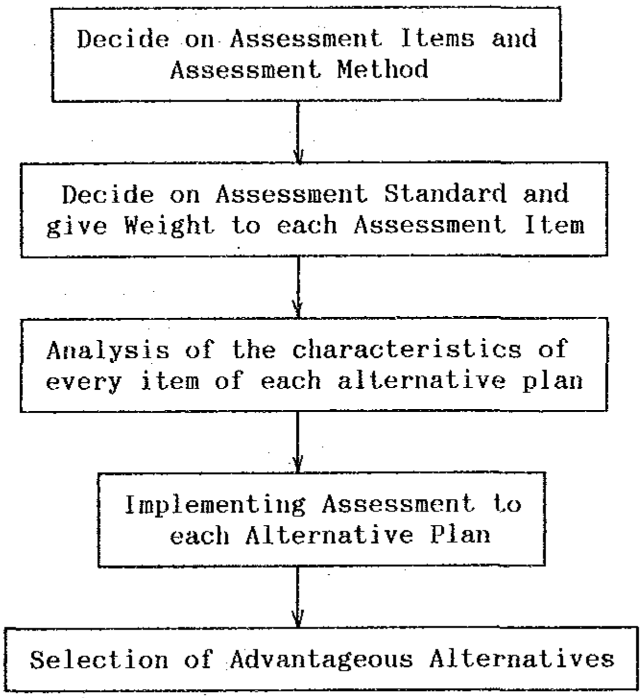


Fig. 8.1 Evaluation flow

8.1 Methodology of Alternative Evaluation

An expressway will affect the future development and determine the direction in which the society in the region will head in economic and social aspects. As such, it is necessary to have an overall assessment based on main factors selected from the 3 areas listed below during the planning stage.

The reference items which form the 3 areas are divided into 'construction period' and 'operational period' and the following items were selected :

1) Construction period

a. Main Technical Factor
   - Traffic Technique : 1 No. of existing lanes to be maintained during construction period i.e., capacity.
     2 Possibility to close the existing road

		i.e., accessibility.
- Structure Technique	:	3 Construction Technique. 4 The length of construction period.
b. Main Economical Factor	:	5 Land Acquisition Cost. 6 Construction Cost.
c. Main Social Factor	:	7 Noise and Vibration during construction.

2) Operational period

a. Main Technical Factor - Traffic Technique	:	1 Capacity based on the geometric structure of the road. 2 Safety based on the geometric structure of the road. 3 The ease to carry out evacuation and the spreading characteristics when an accident occurs.
b. Main Economical Factor	:	4 Fee required for ventilation and displacement of water.
c. Main Social Factor	:	5 Noise and vibration generated. 6 Change in scenery of the region. 7 Community separation done to the region. 8 Flexibility to widen and extend the road. 9 Safety impact on Air base.

The summary of the assessment of each item based on some representative viewpoints is given in Table 8.1.

8.2 Criteria and Weight for Evaluation

After determining each evaluation item, and the method of evaluation, it is required for the reasons described herein after, to weigh each item and normalize the relative scoring. To date no standard system has been developed which could easily be applied in order to evaluate all items *in terms of currency of system. Precision level of Phase I of the Study* is not as accurate as evaluation by equivalency of currency.

Further, the aim of the Phase I Study is to select an advantageous group of alternatives and not to screen out a single plan. Therefore, the evaluation manner adopted herein is to assign weight to items taking into consideration the feature of the route and to put relative score into items. Weight and criteria for evaluation has been finalized in accordance with the agreement between the PWD counterpart and the Study Team. Scoring is on the basis of 5 marks and item weight on the basis of 100 marks. The result is summarized in Table 8.2.

8.3 Analysis on Feature

For assessment on ease of implementation, besides breaking down into necessary work items, the parameters that correspond to the ease of implementation at site for each work item should also be established. The number of spots that have difficulties in implementation should be added up throughout the whole route.

Table 8.1 Items of alternative evaluation

PERIOD	ITEM		EVALUATION DESCRIPTION	EVALUATION Indicative Value
UNDER CONST-RUCTION	Traffic Management	Capacity	Considering the passable road section under construction, the possible traffic volume shall be calculated based on authorised theory such as HCM.	V/C
		Accessibility	To estimate the number of locations where access will be limited during construction work.	N•fE
	Construction	Construction Technic	The safety and security of the construction work shall be selected as the evaluating factor of the item. It also can be said to be the probability of the accidents under construction.	Grading based on experience
		Construction Period	To regard the length of construction period as the effect to road users. Considering the construction methods and construction condition, construction period sshall be estimated.	Construction period
	Environmental Impact	Noise & Vibration	PWL shall be roughly estimated based on statiscally obtained data after determination of construction machines. After then NPL shall be estimated considering the distance.	NPL
	Initial Cost	Land Acquisition & Compensation	In particular for the private land, land acquisition and compensation cost should be estimated roughly.	Cost
		Construction	Based on the information on the length of individual construction work, such as bridge, tunnel and erth work, construction cost shall be estimated roughly.	Cost
AFTER CONST-RUCTION	Traffic	Capacity and Traveling Speed	V/C ratio and traveling speed shall be calculated based on forecasted traffic volume and road condition in accordance with HCM.	V/C
		Safety	Traffic safety shall be estimated comprehensively based on the information, such as horizontal and vertical alignment, location of interchange and connection of roads at interchanges.	Statistical Data
	Environmental Impact	Noise & Vibration	NPL shall be roughly estimated based on the theory which is developed for three road structures, eg viaduct, embankment and cut.	NPL
		Aesthetic	This aspect shall be evaluated qualitatively based on the information, such as shape and scale of road structure and precedents.	Grading based on experience
		Community Separation	Physical separation of community shall be estimated based on the existing land-use type and designed horizontal and vertical alignment.	Location and Magnitude
	Maintenance Cost	Ventilation & Drainage	This cost shall be estimated for the alternative which will have tunnel section, depressed section and viaduct section.	Cost
	Possibility for Future Extension		Due to the physical constraint, the possibolity of widening for some sections shall be considered.	Based on Technical Judgement
	Effectiveness on the Land Usage		The effectiveness of spatial utilization above and beneath roads shall be mesured based on the designed horizontal and vertical alignment and typical crossesections.	Existence of available space
	Disaster	Security of Traffic	The probability of disaster expansion and easiness for rescue activities shall be evaluated based on the physical information on road structure.	Available Space for Rescue Activity
		Security of Airbase	The influence against Air-force of unexpected severe disaster shall be evaluated based on the precedent in Japan.	Based on Technical Judgement

Table 8.2 Criteria for alternative evaluation

PERIOD	ITEM		Score 5	Score 4	Score 3	Score 2	Score 1
UNDER CONST-RUCTION	Traffic Management	Capacity	Less than 0.8	0.8-1.0	1.0-1.1	1.1-1.2	greater than 1.2
		Accessibility	No influence	Slightly affected	Moderate	Fairly severe	Very severe
	Construction	Construction Technic	Very simple	Fairly simple	Standard	Fairly compli-cated	Very compli-cated
		Construction Period	Very short period	Short period	Moderate	Long period	Very long period
	Environmental Impact	Noise & Vibration	No influence	Slightly affected	Moderate	Fairly severe	Very severe
	Initial Cost	Land Acquisition & Compensation	Less than 0.6* Average cost	(0.6-1.0) * Average cost	Average cost	(1.0-1.4) * Average cost	more than 1.4* average cost
		Construction	Less than 0.8* Average cost	(0.8-1.0) * Average cost	Average cost	(1.0-1.2) * Average cost	more than 1.2* average cost
AFTER CONST-RUCTION	Traffic	Capacity and Traveling Speed	Less than 0.7	0.7-0.8	0.8-0.90	0.9-1.0	greater than 1.0
		Safety	Very low possibili-ty of accident	Fairly low possibili-ty of accident	Moderate level	Fairly hi-gh possi-bility of accident	Very high possibi-lity of accident
	Environmental Impact	Noise & Vibration	No influence	Slightly affected	Moderate	Fairly severe	Very severe
		Aesthetic	No influence	Slight pressure	Moderate	Severe pressure	Very severe pressure
		Community Separation	No influence	Slightly affected	Moderate	Fairly severe	Very severe
	Maintenance Cost	Ventilation & Drainage	less than 0.6* Average cost	(0.6-1.0) * Average cost	Average cost	(1.0-1.4) * Average cost	more than 1.4* average cost
	Possibility for Future Extension		Very easy	Fairly easy	Possible	Fairly difficult	Impossi-ble
	Effectiveness on the Land Usage		Very effective use	Fairly effective use	Moderate	Waste land	Waste much land
	Disaster	Security of Traffic	Very easy rescue activity	Easy rescue activity	Under moderate condition	Under limited condition	Under no condition
		Security of Airbase	No danger	Rare	A little	Possible	Most likely