3. EXISTING DRAINAGE CONDITIONS

3.1 Principal Features of Drainage Area

3.1.1 Sg. Air Mendidih Drainage Basin

The drainage area tends to gently slope toward west and southwest as a whole, except for the area in the northeastern sub-basin and the valley-bottom plain along the watercourse. The drainage system is composed of three major drainage sub-systems, namely Line N, Line O and Line P as depicted in Fig. IV-3(1).

From the flood control viewpoints, there are three potential sites in Line N sub-basin. These are:

(a) wide pond of about 2.87 ha in Sek. Men. Sains for on-site detention;

(b) wide playground of 1.14 ha in IKM also for on-site detention; and

(c) wide channel of 480 m long, 13 m wide and 3 m deep in the uppermost reaches for channel storage.

The salient features of Sg. Air Mendidih drainage basin are enumerated below.

Draining area	3.62 km^2
Topography	Hilly areas in the major part and valley-bottom plain
Altitude	0.5-21 m
Tidal effects	Downmost segment (up to Chainage 1,000 m)
Ratio of urban area to whole basin	
Present (as of 1999)	65.8%
Future (in 2005)	82.7%
Future (in 2020)	99.7%
Major part of future development	upper reaches of Line O and Line P
Functional existing detention ponds	nil

3.1.2 Line G Drainage Basin

The topography in the drainage basin is divided into three categories: hills, gently inclined lands and alluvial plains. The hills as represented by Bukit Tok Acheh (EL. 73 m) are located in the northeastern part of the area where the original topography still remains. On the contrary, the intensive land development has brought about a dynamic topographic change through cut and fills in the gentle inclined lands and the alluvial plains. The drainage system is a simple pattern as shown in Fig. IV-3(2).

In the middle reaches, there is a swampy area that has a flood retarding function. This swampy area will be developed with landfill in near future, resulting in depletion of the retarding function.

The highlighted feature of the basin is an existence of the following two detention ponds of which catchment covers 36% of the entire basin.

Name	Catchment Area	Effective Storage	Specific E. Storage
Taman Keladi	69.6 ha	36,050 m^3	520 m^3/ha
Taman Sri Wang	28.1 ha	7,300 m^3	260 m^3/ha

The salient features of Line G drainage basin are enumerated below.

Draining area	2.72 km^2
Topography	Hills, gently inclined lands and alluvial plains
Altitude	1.0-73 m
Tidal effects	Downmost segment (up to Chainage 200 m)
Ratio of urban area to whole basin	
Present (as of 1999)	35.4%
Future (in 2005)	43.3%
Future (in 2020)	87.3%
Major part of future development	Whole area except for south and southeastern parts
Functional existing detention ponds	Two: Taman Keladi and Taman Sri Wang

3.1.3 Prt. Pokok Mangga Drainage Basin

The topography of the entire basin shows a typical coastal plain feature, which is characterized by extremely flat topography and high groundwater level (less than 1 m underneath the ground). Stormwater is complexly drained through the drainage network discharging out into Prt. Pokok Mangga due to flat topography.

The neighboring basin of Prt. Besar Limbongan has suffered from frequent and severe flooding in recent years due to agricultural development in the upper reaches. The study area is extended over Prt. Besar Limbongan basin in response to a strong request of the Melaka Municipal Council.

The salient features of Prt. Pokok Mangga drainage basin are given in the table below.

Draining area	Prt. Pokok Mangga: 2.03 km^2 Prt. Besar Limbongan: 2.68 km^2
Topography	Low-lying coastal plains
Altitude	1.5-4.0 m
Tidal effects	Affecting almost whole stretch
Ratio of urban area to whole basin	
Present (as of 1999)	51.3%
Future (in 2005)	53.4%
Future (in 2020)	99.6%
Major part of future development	Middle reaches
Functional existing detention ponds	nil

3.1.4 Sg. Ayer Salak Drainage Basin

The topography of this drainage basin is classified into two parts: moderately sloping hills in the northern part and coastal and valley-bottom plains in the southern part. The drainage system of Sg. Ayer Salak is composed of one river course and two major trunk drains, namely Sg. Ayer Salak, Prt. AB1 and Prt. AB11 as illustrated in Fig. IV-2(4).

The following detention pond exists in the Prt. AB11 basin collecting stormwater over a part of the Bukit Rambai industrial estate. Its catchment area will increase after completion of a new development that is located in the uppermost reaches, as given below.

Name	Catchment Area	Effective Storage	Specific E. Storage
Bukit Rambai	present: 69.6 ha future: 98.1 ha	15,850 m^3	present: 230 m^3/ha future: 160 m^3/ha

The salient features of Sg. Ayer Salak drainage basin are enumerated below.

Draining area	17.20 km^2 Sg. Ayer Salak: 11.35 km^2 Prt. AB1: 3.65 km^2 Prt. AB11: 2.20 km^2
Topography	Gentle hills, coastal and valley-bottom plains
Altitude	2.0-65 m
Tidal effects	Lower and middle reaches (up to Chainage 5,000 m)
Ratio of urban area to whole basin Present (as of 1999) Future (in 2005) Future (in 2020)	 22.2% 43.2% 99.9%
Major part of future development	Whole area
Functional existing detention ponds	One: Bukit Rambai

3.2 Profiles of Trunk Drain

3.2.1 Definition of Trunk Drain

Trunk Drain has been defined empirically by judging its draining area of around 40 ha or more. In this study, the following definition is employed to select trunk drains.

(a) draining area of around 40 ha or more, and

(b) draining area located in the urbanized/urbanizing area and in the future development area.

The trunk drains are selected in the above-mentioned manner, and the trunk drain's profile is described in the succeeding subsections.

3.2.2 Salient Features of Trunk Drains

Present drainage conditions of major trunk drains are illustrated in Fig. IV-2, and Fig. IV-3 depicts the longitudinal profile of the major trunk drains on which cross-sectional survey was conducted. The whole trunk drain networks are shown in Fig. IV-4, and Table IV-2 summarizes present conditions of the trunk drains.

The following are the salient features of each priority project basin.

(1) Sg. Air Mendidih Drainage Basin

Most segments of the trunk drains and river channels are made of earth bank, excluding the R. C. sections in some residential estates, as depicted in Fig. IV-2(1).

There is a distributary point in the uppermost of Line O and Line P (junction O-1, P-3 and P-4), as illustrated in Fig. IV-4(1). The distributary point to Line O should be closed in due consideration of difficulties in channel improvement for both drains and future increase of flood runoff by land development in Polis Hutan area.

(2) Line G Drainage Basin

The trunk drains in the middle and upper reaches are made of earth bank, while most of the trunk drains in the lower reaches are made of R.C. structure, as depicted in Fig. IV-2(2).

The downstream end of trunk drain G-3 perpendicularly bends to cross the road, as shown in Fig. IV-2(2), and the downstream drains of G-1 and G-2 have small flow capacity as enumerated in Table IV-2. Thus, the diversion with a straight alignment from the end to Sg. Petani along the road can be easily considered as an alternative measure. In this case the diversion will receive the additional discharge from the neighboring drainage basin of 15.73 ha, since a small drain exists along the same route to discharge the stormwater originated from the basin. This discharge is regarded as an external factor for comparative study, and should be included in the detailed design stage. Therefore, this discharge will not consider into design flood discharge in the alternative study described in Chapter 4 and 5.

(3) Prt. Pokok Mangga Drainage Basin

Most of the trunk drains are made of earth channel, excluding the lined channel in the uppermost reaches where the residential estates were developed.

The characteristics of flooding in this area are originated from the topographic conditions of low-lying coastal plains. The flow capacity of the drains is naturally poor due to lack of channel slope. In dry weather the water tends to be stagnant, and waterweeds can thickly grow in the drains resulting in maintenance problems.

In Kg. Limbongan, the stormwater draining from dry-field-cropping farms in the upper reaches causes flooding problems due to lack of proper drainage system in the lower reaches.

(4) Sg. Ayer Salak Drainage Basin

The entire stretch of river channels and trunk drains is made of earth channel, as shown in Fig. IV-2(4). As mentioned in Subsection 3.1.4 the basin is composed of three (3) draining systems, Sg. Ayer Salak, Prt. AB1 and Prt. AB11. The following are particular features of the three (3) draining systems.

(a) Sg. Ayer Salak

The river channel of Sg. Ayer Salak was improved up to Chainage 5,480 m. After completion of the improvement works, the channel has a flow capacity equivalent to a little less than a 5-yr flood.

(b) Prt. AB1

The middle and lower reaches of Prt. AB1 are utilized for irrigation canal. The water for irrigation is diverted from adjacent Sg. Ayer Hitam to upper Prt. AB1. After utilization for irrigation the water returns to Sg. Ayer Hitam in the middle reaches of Prt. AB1.

Prt. AB1 is called Sg. Paya Lebar (wide swamp in English). A wide swampy area extends in the middle reaches, hence its name.

(c) Prt. AB11

Prt. AB11 is a tributary of Prt. AB1 and also has a wide swampy area in the middle reaches.

3.2.3 Flow Capacity of Major Trunk Drains

Flow capacity is computed for river courses and major trunk drains on which cross-sectional survey was conducted, employing non-uniform flow and uniform flow calculations. The results are presented in Fig. IV-5.

As indicated in the figures, flow capacity is extremely lower than the 5-yr flood discharge without any flood detention in most of the river and drainage stretches. In these stretches, channel improvement works must be crucial for flood damage alleviation, especially in urban and urbanizing areas. On the contrary, the upper reaches of Line N in the Sg. Air Mendidih drainage basin are almost satisfactory for the scale of 5-yr flood. Further flow capacity of the lower reaches of Sg. Ayer Salak is a little less than the 5-yr flood discharge. Thus some flood detention may be crucial for flood damage alleviation, since this stretch has been improved in the recent years.

3.3 Major Secondary Drains

Aside from the trunk drains, there are numerous secondary drains in the study area. In the course of field survey, the secondary drains flowing into the river channels or trunk drains were checked through sketch and measurement of their locations and dimensions. Table IV-3 and Fig. IV-6 present the results of the survey. Most of the secondary drains tabulated in Table IV-3 are made of earth channel since their draining areas are not urbanized until now.

The secondary drains as well as the tertiary drains will normally be improved or newly constructed as one of the packaged infrastructures in land development. Difficult is a prediction for the details of land development activities in future. Prior to the secondary drainage improvement, receiving water system of rivers and/or trunk drains should be improved to safely carry out the increased flood discharge by development.

4. ALTERNATIVE DRAINAGE SCHEMES

In this chapter, alternative drainage schemes are proposed in each priority project area, Sungai Petani and Melaka, synthesizing the appropriate measures for its topographic and land use features. In Section 4.1, the applicability of countermeasures over the target drainage areas is summarized. In the succeeding sections, from 4.2 to 4.5, the detailed alternatives are proposed for each drainage area through preliminary screening of applicability based on particular features and localities.

4.1 Overall Applicability of Countermeasures

In due consideration of particular features of topography and land use in each target drainage area, the applicability of possible countermeasures are summarized in the following table.

Applicable Measures	Sg. Petani		Melaka	
	Air Mendidih	Line G	Pokok Mangga	Ayer Salak
Channel improvement	√	√	√	√
Construction of diversion channel including new channeling		√	√	
Construction of pumping stations			√	
Rehabilitation of existing detention ponds		√		√
Construction of detention ponds in newly developed areas	√	√	√	√
Construction of on-site detention ponds in public open spaces	√		√	
Installation of storage tank in individual house	√		√	

Note: √ indicates that countermeasure is applicable to the basin.

4.2 Drainage Basin of Sg. Air Mendidih in Sungai Petani

4.2.1 Possible Countermeasures

The following are possible countermeasures in the Air Mendidih drainage basin, and the locations of these structural measures are shown in Fig. IV-7.

(1) Channel Improvement

The xisting trunk drain network is delineated in Fig. IV-4(1). The channel flow capacity is lower than the peak discharge equivalent to 2-year flood in most of the stretches of Sg. Air Mendidih, Lines N, O and P, except for the upper reaches of Line N, as depicted in Figs. IV-5(1) to IV-5(3). Thus channel improvement might be still one of the principal measures in the basin.

At present an earth drain collecting water from Polis Hutan bifurcates in the upper-most portion of Line P and Line O. In due consideration of difficulties for channel improvement and future development of Polis Hutan, the earth drain is to be connected to Line P and the upper-most of Line O is to be closed at the bifurcation point. As a result, a segment of the earth drain is designated as P-4, as shown in Fig. IV-4(1).

Further, preliminary channel design is enumerated below.

(a) Down-most Section

Compared with deepest riverbed elevations of the adjacent mouths of Sg. Petani and Sg. Air Mendidih, the design invert level of –1.0 m at the mouth is determined.

River/Drain	Mouth/Adjacent Section	Riverbed Elevation
Sg. Petani	CH 5,711 m	-1.78 m
	CH 5,806 m	-1.57 m
Sg. Air Mendidih	CH 0 m	-0.95 m

(b) Design Invert Level and Slope

Starting from the mouth in parallel with the existing channel bed, the design invert level is determined. Design channel slope changes mainly at the junctions of major tributaries and the points of topographical changes.

(c) Design Bank, High-water Level and Depth

High-water level is set up, enveloping the existing bank and delineating the parallel line to design channel-bed. Freeboard of 0.3 m is added to determine design bank level. Backwater effect from Sg. Petani is not considered since the bank level of Sg. Air Mendidih is higher than that of Sg. Petani. As a result, design water depth is 2.0 m over the whole stretch.

(d) Drain Type

The following drain type is determined in accordance with the criteria, as described in Subsection 2.2.1.

Drain	Segment	Drain Type
Air Mendidih	CH 0 m - CH 1,310 m	Earth drain
Line N	CH 1,310 m - CH 1,740 m	Earth drain
	CH 1,740 m - CH 2,400 m	R.C. drain
Line O	CH 0 m - CH 630 m	R.C. drain
Line P	CH 0 m - CH 1,410 m	R.C. drain

(2) Construction of Detention Pond in Newly Developed Area

The wide vacant lands to be developed in future are mainly located in the upper reaches of Line P and Line O. Reconnaissance survey was made so as to clarify the adequacy for construction of detention facilities in those areas. As a result, the following two sites are suitable for construction of new detention ponds taking into account the existing drainage system and topography.

Location of proposed pond		Polis Hutan	Upper Line P
Topography		Flat land	Valley-bottom plain
Type of pond		Embankment and excavation	Retarding basin with broad-crested side-overflow weir
Catchment area (ha)		54.49	84.82
Approx. dimension	Ponding area (m^2)	25,400	10,200
	Maximum storage depth (m)	2.6	1.5
	Storage volume (m^3)	48,700	8,900
	Specific storage volume (m^3/ha)	890	100

The detention pond for Upper Line P should be designed through integrating the new development activities in the Sg. Air Mendidih basin except for the Polis Hutan area. A retarding basin type of pond with broad-crested side-overflow weir might be suitable since these ponding areas are located along the wide valley of trunk drains with a gentle slope.

(3) Construction of On-site Detention Pond in Public Open Space

There are two suitable sites of institutional areas for construction of on-site detention ponds. The following are location and approximate potential storage volume estimated on the basis of topographic map with a scale of 1:2,000.

Name	Sek. Men. Sains	IKM
Catchment area (ha)	15.0	7.4
Ponding area (ha)	2.9 (pond) 2.5 (ground)	1.1 (ground)
Storage depth (m)	0.6 (pond) 0.2 (ground)	0.3 (ground)
Storage volume (m^3)	22,400	3,300
Specific storage volume (m^3/ha)	1,490	450

These on-site detention ponds would function well, judging from their specific storage volumes to be ensured.

In addition, the drains in Upper Line N, which are located in the residential estates of Taman Peruda and Taman Bandar Baru Azham, have a quite large amount of storage volume. This amount of available channel volume can be utilized for flood control through installation of an appropriate control structure of outlet. The approximate channel volume is as follows.

Sectional area of drain (m^2)	20
Drain length (m)	800
Storage volume (m^3)	16,000
Catchment area (ha)	59.4
Specific storage volume (m^3/ha)	270

(4) Installation of Storage Tank in Individual House

A storage tank will be installed in an individual house in the existing built-up area. A typical prototype of storage tank is tabulated below based on the drainage structure plan study.

Average extent of house lot (m^2)	200
Storage volume of a tank (m^3)	2
Specific storage volume (m^3/ha)	100
Extent of existing built-up area (ha)	167.65

4.2.2 Alternative Drainage Schemes

Among the preceding countermeasures, the following alternative drainage schemes are studied.

Countermeasures	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Channel improvement	√	√	√	√
Construction of detention ponds in newly developed areas		√	√	√
Construction of on-site detention ponds in public open space			√	√
Installation of storage tank in individual house				√

The following are the notion of each alternative:

Alt. 1 : Conventional structural method of drainage improvement
Alt. 2 : Modification of present regulatory policy
Alt. 3 : Additional effects of on-site detention
Alt. 4 : Additional effects of individual house storage

4.3 Drainage Basin of Line G in Sungai Petani

4.3.1 Possible Countermeasures

The following are possible countermeasures for Line G drainage basin, and the locations of these structural measures are shown in Fig. IV-8.

(1) Channel Improvement

The existing and proposed trunk drain network is delineated in Fig. IV-4(2). The channel flow capacities in the lower reaches are longitudinally unbalanced as shown below.

Chainage	200-400m	400-800m
Drain type	R.C roadside drain	R.C drain
Approximate drain size	w: 1.0m, d: 1.6m	w: 3.1m, d: 1.4m
Channel slope	0.20%	0.42%
Flow capacity	2.7 m^3/s	14.9 m^3/s

Channel improvement also might be one of the principal measures in the basin so as to ensure the drainage network longitudinally well balanced.

Further, preliminary channel design is enumerated below.

(a) Down-most Section

Compared with the deepest riverbed elevations of adjacent mouths of Sg. Petani and Line G, the design invert level of –0.60 m at the mouth is determined.

River/Drain	Mouth/Adjacent Section	Riverbed Elevation
Sg. Petani	CH 7,193 m	-0.87 m
	CH 7,297 m	-1.01 m
Line G	CH 0 m	-0.53 m

(b) Design Invert Level and Slope

Starting from the mouth in parallel with the existing channel-bed, the design invert level is determined. Design channel slope changes mainly at the points of topographic change.

(c) Design Bank, High-water Level and Depth

High-water level is set up, enveloping the existing bank and delineating the parallel line to design channel-bed. Freeboard of 0.3 m is added to determine design bank level. Backwater effect from Sg. Petani is not considered, since the bank level of Line G is higher than that of Sg. Petani. As a result, design water depth is 2.0 m over the whole stretch.

(d) Drain Type

The following drain type is determined in accordance with the criteria, as described in Subsection 2.2.1.

Drain	Segment	Drain Type
Line G	CH 0 m - CH 2,860 m	R.C drain
Taman Keladi	CH 0 m - CH 180 m	R.C drain

(2) Construction of Diversion Channel

From the above unbalanced situation of the lower part of Line G, the diversion with straight alignment along the major road can arise as an alternative measure. In this alternative, the drainage area will be slightly changed. The down-most sub-basin will be detached from the Line G basin, while the neighboring basin on the north side, of which drain already runs along the same route, will be annexed to the Line G basin. As a result of this alternative, the catchment areas will be changed as follows.

Original Line G basin	:	272.8 ha
Line G basin in diversion alternative	:	271.2 ha
Remaining down-most basin	:	17.3 ha

In the feasibility study, however, the following draining area shall be used excluding the neighboring basin, for reason of economic comparison between the original drainage network and the modified network with diversion within the same basin.

Original Line G basin	:	272.8 ha
Line G basin in diversion alternative	:	255.5 ha
Remaining down-most basin	:	17.3 ha

Further, preliminary design of the diversion is enumerated below.

(a) Invert Level of Diversion Outfall

Referring to the deepest riverbed elevations of the adjacent Sg. Petani, design riverbed level of –0.40 m is determined for design invert level of the diversion outfall.

River/Drain	Adjacent Section	Riverbed Elevation
Sg. Petani	CH 7,593 m	-0.60 m
	CH 7,693 m	-0.20 m

(b) Design Invert Level

Starting from the mouth to connect to the design channel-bed at the diversion point, design invert level is determined.

(c) Drain Type

The drain type of diversion is the R.C drain, same as the Line G drain.

(3) Rehabilitation of Existing Detention Ponds

There are two existing functional detention ponds in the Line G basin. The salient features of the two ponds and possibility for rehabilitation are summarized in the following table.

Name	Taman Keladi		Taman Sri Wang	
	Present	After rehabilitation	Present	After rehabilitation
Catchment area	69.6 ha		28.1 ha	
Area of pond	18,850 m^2	25,680 m^2	6,230 m^2	6,870 m^2
Maximum depth	3.0 m	3.6 m	2.1 m	3.5 m
Effective depth	2.4 m	3.0 m	1.5 m	2.9 m
Gross storage	47,610 m^3	79,380 m^3	10,780 m^3	20,890 m^3
Effective storage	36,050 m^3	63,000 m^3	7,300 m^3	16,800 m^3
Specific effective storage	520 m^3/ha	910 m^3/ha	260 m^3/ha	600 m^3/ha

The following are the principal measures to rehabilitate the two ponds.

(a) In order to increase the storage volume, the ponding area shall be extended as wide as possible within the extent of the site.

(b) For the same purpose, pond surface shall be excavated as deep as possible within an adjustable height to the downstream drain channel.

(c) In order to enhance the deteriorated environmental situations, installation of trash rakes, improvement of inlet and outlet structures, and construction of dry-weather channel or bypass sewer shall be considered.

(4) Construction of Detention Ponds in Newly Developed Areas

The wide vacant lands to be developed in future are mainly located in the middle and upper reaches of Line G. The following two detention ponds can be planned in accordance with the existing drainage system and locations of new development.

Location of proposed pond		Upper Line G	Middle Line G
Topography		Valley-bottom plain	Swampy area
Type of pond		Retarding basin with broad-crested side-overflow weir	Retarding basin with excavated dry-weather channel
Catchment area (ha)		179.53	232.70
Approx. dimension	Ponding area (m^2)	18,200	42,500
	Maximum storage depth (m)	2.0	1.8
	Storage volume (m^3)	24,700	48,300
	Specific storage volume (m^3/ha)	140	210

Both detention ponds should be designed through integrating the new development activities in the entire Line G basin. Regarding the pond planned in the middle reaches, a retarding basin with excavated dry-weather channel might be suitable since the ponding area is located in the wide swampy area and untreated domestic wastewater is anticipated flowing into the pond.

4.3.2 Alternative Drainage Schemes

Among the preceding countermeasures, the following alternative drainage schemes are studied.

Countermeasures	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Channel improvement	√	√	√	√
Construction of diversion channel				√
Rehabilitation of existing detention ponds		√	√	√
Construction of detention ponds in newly developed areas			√	√
Note: (√) means selection of better alternative with/without diversion.				

The following are the notion of each alternative:

Alt. 1	:	Conventional structural method of drainage improvement
Alt. 2	:	Effects of pond rehabilitation
Alt. 3	:	Modification of present regulatory policy
Alt. 4	:	Effects of diversion channel