(d) Silau river

In the Silau river, especially downstream of Kisaran, the river bed fluctuation shows a tendency of gradual aggradation. Owing to the river bed aggradation the flow area of river channel becomes smaller and the recent flood overflowed the right bank and inflicted some damages to the downstream areas. The sediment production rate seems to be higher.

(e) Asahan river and others

Due to the sediment deposition at the river mouth of the Asahan river, water depth has decreased and the navigation of big ship is becoming difficult even in high tide. In the upper reaches of Asahan river and other rivers, sedimentation seems to be not a serious problem.

2. Sedimentation of Silau and Asahan River

The annual sediment runoff and river bed fluctuation were estimated for the following river reaches where the urgent flood control plan is prepared.

- Silau River : From Kisaran to the confluence with the Asahan river.
- Asahan River : From the Pulau Raja to the confluence with the Silau river.

(1) Modeling

For sedimentation study of the Silau and Asahan rivers, the basin can be divided as follows: (Refer to Fig. E-4)

<u>Silau River</u>

Zone - S1 : Mountain and hill area, upstream of Kisaran, 1,050 km^2, primary sediment production and transportation occurs.

Zone - S2 : Alluvial plain area, downstream of Kisaran to the confluence at Asahan River (Tg. Balai), 151 km^2, little sediment production, sediment transportation zone.

Asahan River

Zone - A0 : Lake Toba catchment area, 3,674 km^2, no sedimentation (for river bed material).

Zone - A1 : Mountain and hill area between Regulating dam and Pulau Raja, 812 km^2, primary sediment production and transportation occurs.

Zone - A2 : Alluvial plain area including swamp between Pulau Raja and Tg. Balai, 1,216 km^2, little sediment production, sediment transportation zone.

Zone - A3 : Estuary between Tg. Balai and the sea, sediment transportation to the sea occurs by both river flow and tidal flow.

(2) River conditions

The river conditions of the Silau between Kisaran and Tanjung Balai (Zone - S2) and of the Asahan between Pulau Raja and Tanjung Balai (Zone - A2), are summarized as follows. (Refer to Figs. E-5 to E-9)

(a) Channel geomorphology

The river length, mean with and mean river bed slope of the Silau Zone - S2 are respectively 22 km, 125 m and 1/1,700. Those of the Asahan River zone - A2 (from Pulau Raja to the confluence with the Lebah River, Zone - A21) are respectively 58 km, 75 m and 1/6,000. As to the rest reaches up to Tanjung Balai in Zone - A2 (Zone - A22), the river length is 11 km, the river width becomes wider in the downstream reaches and 600 m at Tanjung Balai, and the river bed slope is nearly level.

(b) Flow and sediment discharge capacity

The flow capacity of Zone - S2 is 800 m^3/sec at Kisaran and becomes smaller in the lower reaches to 150 m^3/sec near Tanjung Balai. That of Zone - A2 is 1,300 m^3/sec at Pulau Raja and 200 m^3/sec - 450 m^3/sec through the lower reaches.

The sediment discharge capacity of flow discharge 100 m^3/sec is 10^{-1} - 10^{-3} m^3/sec in Zone - S2, 10^{-1} - 10^{-4} m^3/sec in Zone - A21 and 10^{-2} - 10^{-7} m^3/sec in Zone - A22. In sediment discharge capacity, Zone - S2 of the Silau river is larger than Zone - A2. That in Zone - A22 of the lower reaches of the Asahan river is very small because of the wide river width.

(c) River bed materials

In Zone - S2 of the Silau river and Zone - A2 of the Asahan river, the river bed materials is almost uniform sand (uniformity coefficient = 1.5) and its mean grain size is 0.7 mm in Zone - S2 and 0.5 mm in zone - A2. For each zone, there is little difference in grain size distribution between the upper and lower reaches. The specific gravity of these sands is around 2.60 g/cm^3.

(d) Regime of river bed and sediment transportation

Judging from the river bed materials and hydraulic data, the river bed regime (or form of river bed roughness) must be ripple, and the sediment transportation regime (or form of sediment transportation) is a mixed type with suspended load and bed load.

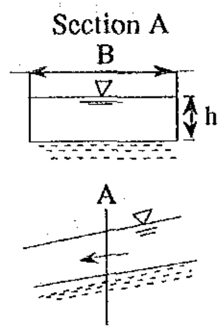
(3) Sediment runoff and river bed fluctuation

(a) Reference points

For Zone - S2 of the Silau river, the reference points of sediment inflow and outflow are respectively Kisaran and the confluence with the Asahan River at Tanjung Balai. For Zone - A2 of the Asahan River, the reference point of sediment inflow is Pulau Raja and that of sediment outflow is set at the confluence with the Lebah river because the sediment discharge capacity by river flow is obviously small due to wide river width and the sediment transportation supposed to be controlled by tidal flow in the river reaches between that point and Tanjung Balai.

(b) Sediment discharge formula

Considering the form of sediment transportation(for both zone, river bed materials are carried in the form of suspended load and bed load), Brown Formula of Eq. 1 that is suitable for this type of sediment transportation form is applied as shown below:



$$\Phi B = 10\varphi^{2.5} \quad \text{--------------------------} \quad 1$$

(Brown Formula)

where, $\Phi B = \frac{qB}{\sqrt{Sgdm}}$

(non-dimensional sediment discharge)

$$\Phi = \frac{Ur_*^2}{Sgdm} = \frac{RIe}{Sdm}$$

(non-dimensional tractive force)

qB	:	sediment discharge per unit width
S	:	specific gravity of sediment grain in fluid
g	:	acceleration of gravity
dm	:	mean grain diameter
U_*	:	friction velocity

$$U_* = \sqrt{\frac{To}{\eta}} = \sqrt{gRIe}$$

To	:	tractive force
η	:	density of fluid

R	:	hydraulic radius
Ie	:	energy slope of flow

Eq. 1 is written as Eq. 2 and 3.

$$\frac{qB}{\sqrt{Sgdm}} = 10 \cdot \left(\frac{RIe}{Sdm}\right)^{2.5} \quad \text{--} \quad 2$$

$$qB = C\,(RIe)^{2.5} \qquad C = \frac{10 \cdot g^{0.5}}{S^2 \cdot dm} \quad \text{----------------------------} \quad 3$$

Total sediment discharge of river section (QB) is obtained from Eq. 4.

$$QB = B \cdot qB \qquad \text{--} \qquad 4$$

Using Eq. 3, Eq. 4 can be re-written as Eq. 5.

$$QB = C' (RIe)^{2.5} \quad C' = \frac{10 \cdot Bg^{0.5}}{S^{2} \cdot dm} \qquad \text{------------------------------} \qquad 5$$

From Manning formula (Eq. 6), energy slope of flow (Ie) is obtained as Eq. 7.

$$V = \frac{1}{n} \cdot R^{2/3} . Ie^{1/2} \qquad \text{------------------------} \qquad 6$$

where,

$$Ie = \frac{V^{2}.n^{2}}{R^{4/3}} \qquad \text{------------------------------------} \qquad 7$$

n : Manning roughness coefficient

By substituting Eq. 7 into Eq. 5, Eq. 5 is rearranged as Eq. 8.

$$QB = \frac{10 \cdot g^{0.5} \cdot B \cdot V^{5} \cdot n^{5}}{S^{2} dm R^{5/6}} \qquad \text{--------------------} \qquad 8$$

Here, if the constant values: $g = 9.8$ m/sec^2, $S = 1.6$, $d = 0.7$ mm (for Silau river) and 0.5 mm (for Asahan river) are given, Eq. 8 can be written as Eq. 9.

$$QB = C \frac{B(V.n)^{5}}{R^{5/6}} \qquad \text{--} \qquad 9$$

C = 17,459 for Silau River
24,475 for Asahan River

(c) Sediment discharge rating curves

Two kinds of sediment discharge rating curve are established as shown below (Refer to Figs. E-10 and E-11). The one is the rating curve for wash load that is prepared on the basis of the existing and new sampling data. The other is the rating curve for river bed materials that is prepared on the basis of the hydraulic data and the above mentioned formula.

- Sediment discharge rating curve for wash load

$$Qsw = 1.0 \times 10^{-6} \times Q^2 \quad \text{(for Silau river at Kisaran)}$$
$$Qsw = 2.5 \times 10^{-7} \times Q^2 \quad \text{(for Asahan river at Pulau Raja)}$$

where, Qsw : sediment discharge of wash load (m^3/sec)
Q : flow discharge (m^3/sec)

- Sediment discharge rating curve for river bed materials

(Silau river)

$$Qs = 4.867 \times 10^{-5} \times Q^{1.343} \quad \text{(sediment inflow at Kisaran)}$$
$$Qs = 3.519 \times 10^{-7} \times Q^{2.421} \quad (Q \leq 150\ m^3/sec)$$
sediment outflow at Tanjung Balai

$$Qs = 6.527 \times 10^{-2} \quad (Q > 150\ m^3/sec)$$

(Asahan river)

$$Qs = 1.340 \times 10^{-6} \times Q^{1.685} \quad \text{(sediment inflow at Pulau Raja)}$$
$$Qs = 5.373 \times 10^{-10} \times Q^{3.073} \quad (Q \leq 350\ m^3/sec)$$
sediment outflow at confluence with Lebah River

$$Qs = 3.533 \times 10^{-2} \quad (Q > 350\ m^3/sec)$$

where, Qs : sediment discharge of river bed materials

(d) Estimation of Sediment Runoff and River Bed Fluctuation Using the above mentioned rating curves and annual mean discharge (shown in Fig. E-1), sediment inflow and outflow are estimated for Zone - S2 of the Silau river and Zone - A22 of the Asahan river. The river bed fluctuation is also estimated by the following equation on the assumption that the annual sediment balance estimated be equivalent to the change of river bed height (Refer to Tables E-2 to E-4).

$$Z = \frac{\Delta Qs}{B \cdot \Delta X \cdot (1 - \lambda)} \times \Delta t$$

where, ΔZ : annual mean fluctuation of river bed
ΔQs : annual sediment balance
B : mean river width
ΔX : total river length
λ : void ratio (= 0.4)
Δt : time (= one year)

The results of estimation are as follows:

= Annual Sediment Balance =

Silau River (Kisaran - Tg. Balai)

(1)	Flow	:	$2{,}003 \times 10^6 m^3$	
(2)	Wash Load Inflow	:	$156 \times 10^3 m^3$	(78 ppm)
(3)	River Bed Materials Inflow	:	$423 \times 10^3 m^3$	(211 ppm)
(4)	Total Sediment Inflow	:	$579 \times 10^3 m^3$	(289 ppm)
(5)	River Bed Materials Outflow	:	$324 \times 10^3 m^3$	
(6)	Balance of River Bed Materials	:	$99 \times 10^3 m^3$	
(7)	River Bed Fluctuation	:	6.0 cm	

Asahan River (Pulau Raja - Lebah River)

(1)	Flow	:	$4{,}695 \times 10^6 m^3$	
(2)	Wash Load Inflow	:	$202 \times 10^3 m^3$	(43 ppm)
(3)	River Bed Materials Inflow	:	$210 \times 10^3 m^3$	(45 ppm)
(4)	Total Sediment Inflow	:	$412 \times 10^3 m^3$	(88 ppm)
(5)	River Bed Materials Outflow	:	$197 \times 10^3 m^3$	
(6)	Balance of River Bed Materials	:	$13 \times 10^3 m^3$	
(7)	River Bed Fluctuation	:	0.5 cm	

= Specific Sediment Yields (S.S.Y.) =

Silau River (at Kisaran, 1,050 km^2)

(1)	S.S.Y. of Wash Load	:	149 $m^3/km^2/year$
(2)	S.S.Y. of River Bed Materials	:	403 $m^3/km^2/year$
(3)	Total S.S.Y.	:	552 $m^3/km^2/year$

Asahan River (at Pulau Raja, 812 km^2 excl. Lake Toba catchment area)			
(1)	S.S.Y. of Wash Load	:	249 m^3/km^2/year
(2)	S.S.Y. of River Bed Materials	:	259 m^3/km^2/year
(3)	Total S.S.Y.	:	508 m^3/km^2/year

3. Conclusion and Recommendation

(1) Present conditions on sedimentation

In the Silau river between Kisaran and Tanjung Balai, the river bed fluctuation shows a tendency of gradual aggradation. Because of this, section area of river channel becomes smaller and the flood has recently overflowed the right bank and given some damages in the downstream areas. Due to the sedimentation at the mouth of the Asahan river, water depth has decreased and the navigation of big ship is becoming difficult even in the high tide time.

(2) Sediment production

There are no large scale mountain break and land slide in the watershed. The most sediments which are supplied into the river channel are considered to be produced by the sheet erosion mainly in the mountain and hill area. According to the estimation of sediment runoff, the specific total sediment yield is 500 - 550 m^3/km^2/year. The specific sediment of river bed materials is about 400 m^3/km^2/year for the Silau river and about 260 m^3/km^2/year for the Asahan river. The value of the Silau river is 1.5 times larger than that of the Asahan river.

(3) Sediment deposition

The annual sediment runoff of river bed materials is 423 x 10^3m^3 at Kisaran and 324 x 10^3m^3 at Tanjung Balai in the Silau river. The annual balance is deposition of 99 x 10^3m^3 and mean river bed aggradation of 6 cm/year. In the Asahan river, the amount of annual sediment runoff at Pulau Raja and the confluence with the tributary Lebah river, are 210 x 10^3m^3 and 197 x 10^3m^3 respectively. The annual balance is deposition of 13 x 10^3m^3 and aggradation of 0.5 cm/year. These values are smaller than those of the Silau river. However, in the lower reaches between confluence of Lebah river and the river mouth, the river width becomes wider and the capacity of sediment transportation is very small. Through these reaches sediments seem to be carried by tidal flow.

(4) Recommendation for flood control plan

In the Silau river, the sediment runoff and river bed aggradation are larger in comparison with other rivers. If the sedimentation of the Silau river remains within this extent, stable river course will be established by designing appropriate cross section and longitudinal section of the river. However, in the case that extensive and new plantation development in the upperstream areas would be planned, it is recommended that the possible measure of check dam to reduce sediment runoff should be studied in the planning.

Table E-1 General Information of Sedimentation for Objective Rivers

Items \ Rivers	Asahan	Silau	Kualuh	Bunut
Catchment Area (km²)	6,903.5 (at T.Balai inc. Silau R.) 5,702.1 (at T. Balai exc. Silau R.) 3,674.0 (Toba Lake Catchment area)	1,201.4 (at T. Balai	3,909.4	867.5 (Upstream from Kiri Kiri. R.)
River length (km)	139 (Sakur R.)	124	198	81
Watershed Height (EL.m)	1,450	1,800	1,700	420
Mean Basin Slope	0.0104 (1/100)	0.0145 (1/70)	0.0086 (1/120)	0.0052 (1/190)
River Bed Materials	Through the alluvial plain, river bed materials are uniform sand.			
Hydrology	Mean annual rainfall is about 2,000 mm in the alluvial plain area, but increased up to some 3,500 mm in the mountain area.			
Geology	Mountain area : tertiary volcanic rocks Low hilly area: laterite underlain by soft white tuff Alluvial plain: fine silty soils			
Land Use	Mountain area : mostly forest Low hilly area: oil palm and rubber plantation Alluvial plain: paddy field, coconut plantation, bush and swamp.			

Table E-2 Annual sediment Runoff Volume at Kisaran

Sediment	Discharge Range	Mean (m^3/s) Discharge	Rating Curve	Days	Sediment Volume ($10^3 m^3$)
	0 - 50m^3/s	39.53		143.57	19.4
	50 - 100	67.45		181.25	71.2
	100 - 150	117.53	$Q_{sw} = 1.0 \times 10^{-6} Q^2$	32.98	39.4
	150 - 200	166.28		4.89	11.7
Wash	200 - 250	217.93		1.41	5.8
Load	250 - 300	280.47		0.58	3.9
	300 - 350	311.30		0.08	0.7
	350 - 400	381.60		0.08	1.0
	400 - 450	415.30		0.08	1.2
	450 - 500	457.40		0.08	1.4
	< Total>	(64)	-	365	155.7
	0 - 50m^3/s	39.53		143.57	84.2
	50 - 100	67.45		181.25	218.0
Suspended	100 - 150	117.53		32.98	83.6
Load	150 - 200	166.28		4.89	19.8
	200 - 250	217.93	$Q_s = 4.867 \times 10^{-5} \times Q^{1.343}$	1.41	8.2
and	250 - 300	280.47		0.58	4.7
Bed	300 - 350	311.30		0.08	0.8
	350 - 400	381.60		0.08	1.0
Load	400 - 450	415.30		0.08	1.1
	450 - 500	457.40		0.08	1.3
	< Total>	(64)	-	365	422.7
< Ground Total>				365	578.4

Table E-3 Annual Sediment Runoff Volume at Pulau Raja

Sediment	Discharge Range	mean (m^3/s) Discharge	Rating Curve	Days	Sediment Volume(10^3m^3)
Wash Load	50 - 100m^3/s	87.50		78.91	13.0
	100 - 150	127.74	Qws =	139.16	49.0
	150 - 200	169.39	$2.5x10^{-7}xQ^2$	99.89	61.9
	200 - 250	221.46		21.41	22.7
	250 - 300	271.00		9.09	14.4
	300 - 350	322.95		13.16	29.6
	350 - 400	361.10		2.59	7.9
	400 - 450	432.03		0.48	1.9
	450 - 500	460.27		0.31	1.4
	<Total>	(149)	-	365	201.8
Suspended Load and Bed Load	50 - 100m^3/s	87.50		78.91	17.1
	100 - 150	127.74		139.16	57.1
	150 - 200	169.39	Qs =	99.89	65.9
	200 - 250	221.46	$1.340x10^{-6}xQ^{1.685}$	21.41	22.2
	250 - 300	271.00		9.09	13.2
	300 - 350	322.95		13.16	25.7
	350 - 400	361.10		2.59	6.2
	400 - 450	432.03		0.48	1.5
	450 - 500	460.27		0.31	1.1
	<Total>	(149)	-	365	210.0
<Ground Total>				365	411.8

Table E-4 Annual Sediment Outflow at Lower Reaches of Silau R. and Asahan R.

Section	Discharge *1 Range (m^3/s)	Mean *2	Rating Curve	Days	Sediment Volume($10^3 m^3$)
Silau R.	0 - 50m^3/s	39.53	Qs = $3.519x10^{-7}xQ^{2.421}$	143.57	32.1
	50 - 100	67.45		181.25	147.6
	100 - 150	117.53		32.98	103.0
	150 - 200	166.28	Qs = $6.527x10^{-2}m^3/s$	4.89	27.6
	200 - 250	217.93		1.41	8.0
	250 - 300	280.47		0.58	3.3
	300 - 350	311.30		0.08	0.5
	350 - 400	381.60		0.08	0.5
	400 - 450	415.30		0.08	0.5
	450 - 500	457.40		0.08	0.5
	< Total>			365	323.6
Asahan R.	50 - 100m^3/s	105	Qs = $5.373x10^{-10}xQ^{3.073}$	78.91	6.0
	100 - 150	153		139.16	33.4
	150 - 200	203		99.89	57.2
	200 - 250	266		21.41	28.1
	250 - 300	325		9.07	22.0
	300 - 350	-	Qs = $3.533x10^{-2}m^3/s$	13.16	40.1
	350 - 400	-		2.59	7.9
	400 - 450	-		0.48	1.5
	450 - 500	-		0.31	0.9
	< total>	-		365	197.1

Note :

*1 : Discharge at Kisaran and Pulau Raja

*2 : For Asahan R., mean discharge is multiplied by 1.2 considering the downstream area of Pulau Raja.

Fig. E-1 Hydrology for Sdimentation Study

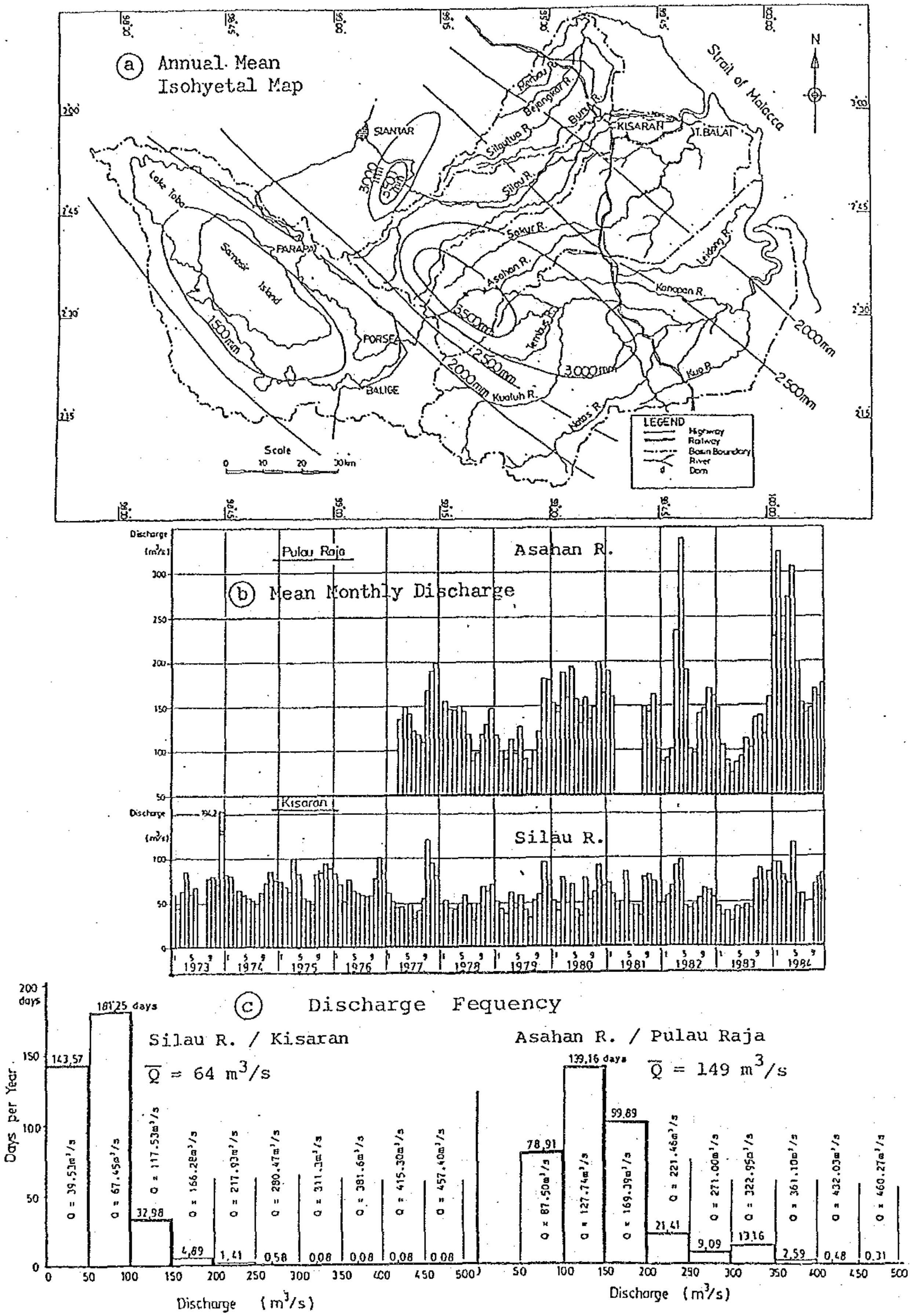


Fig. E-2 Topographical Basin Profile

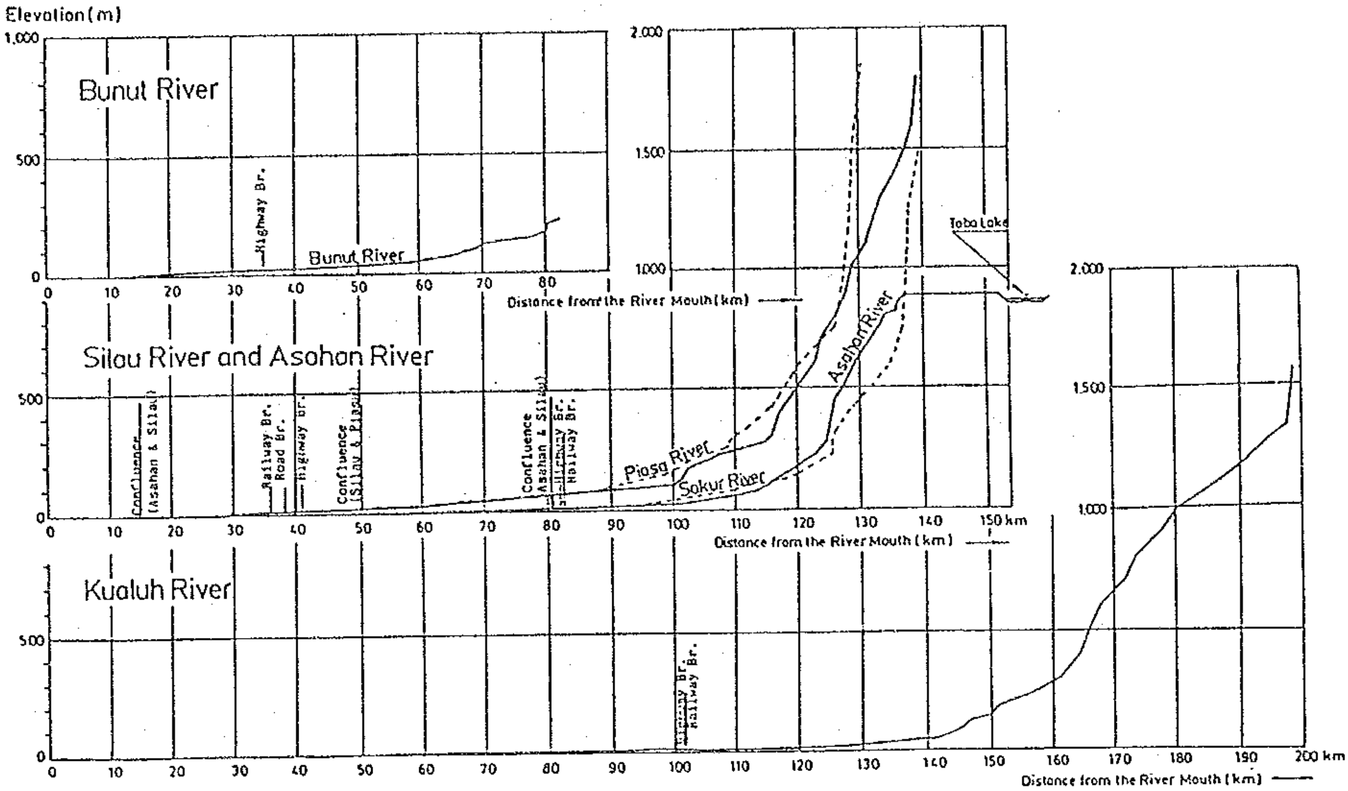


Fig. E-3 Geological Basin Profile

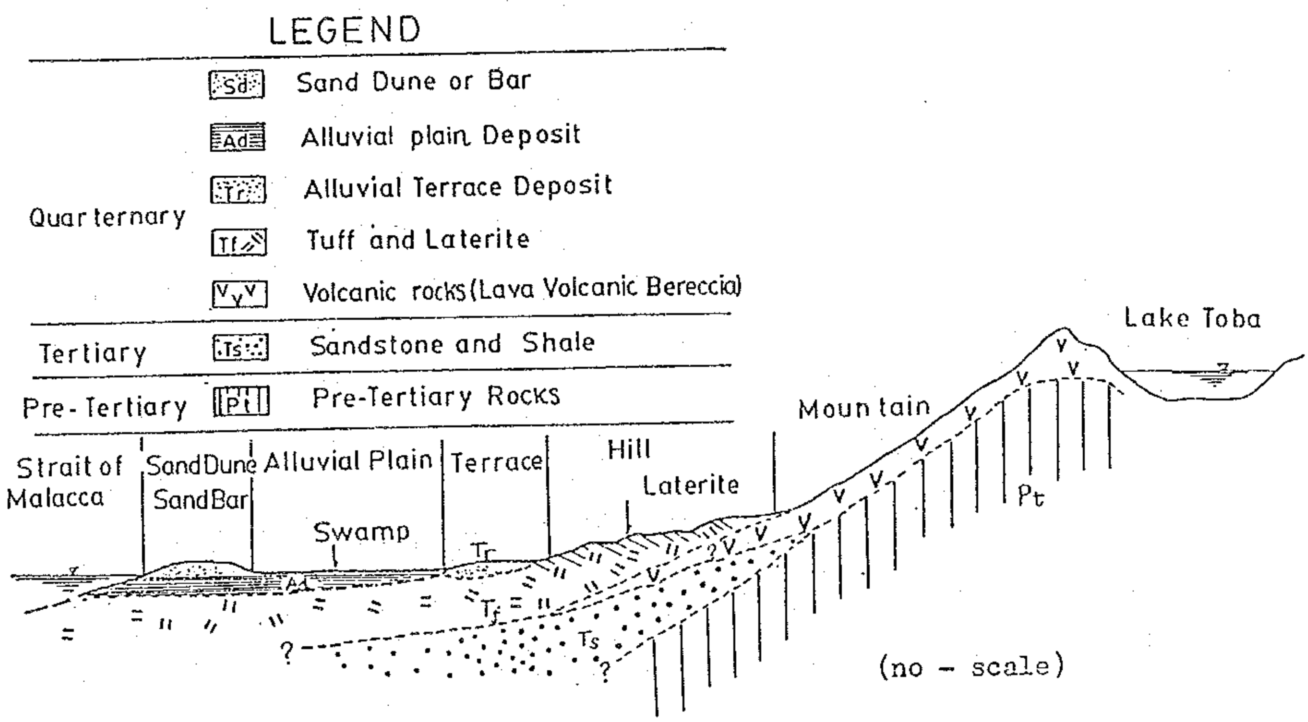
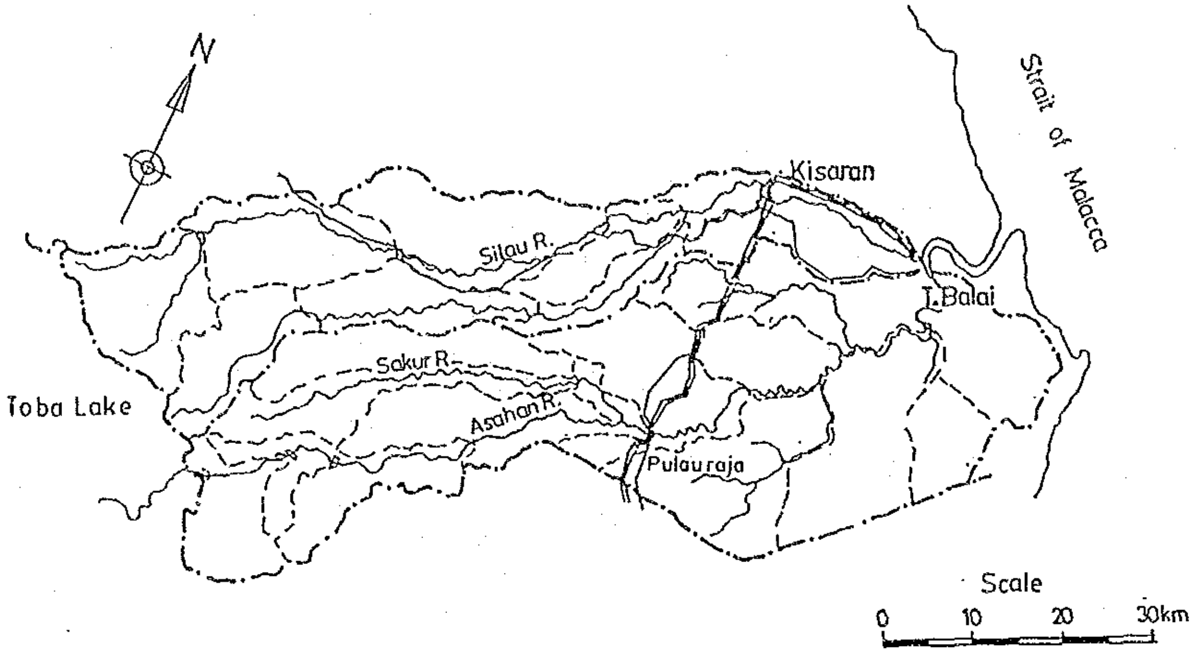
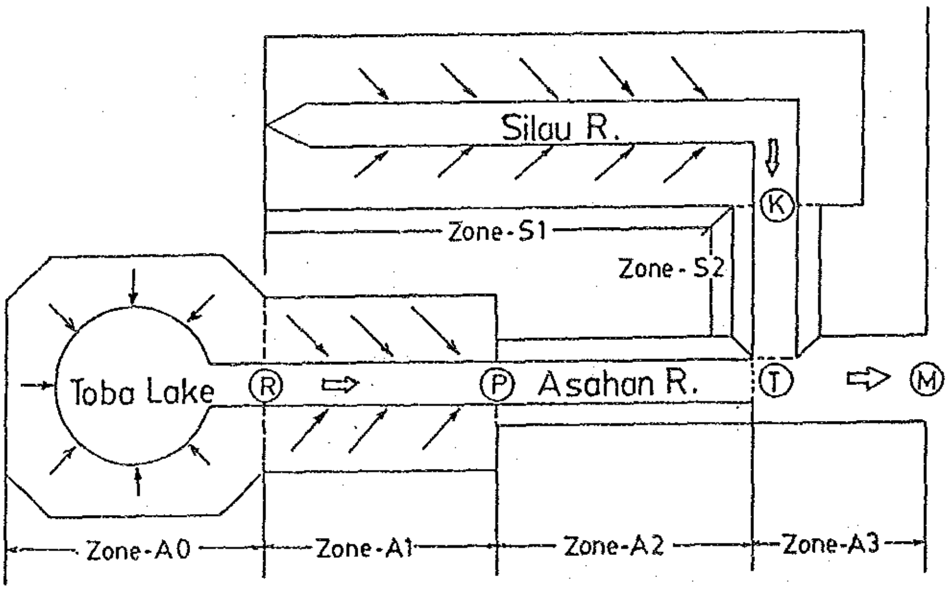


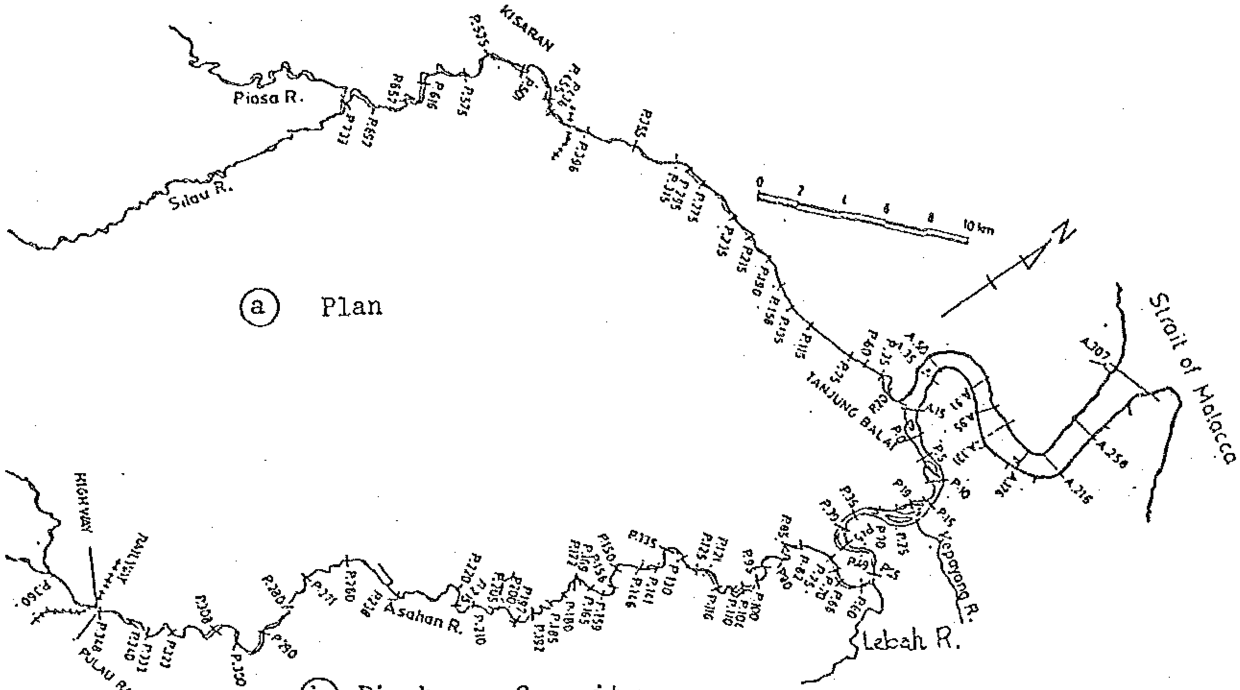
Fig. E-4 Sedimentation Modeling for Silau and Asahan River





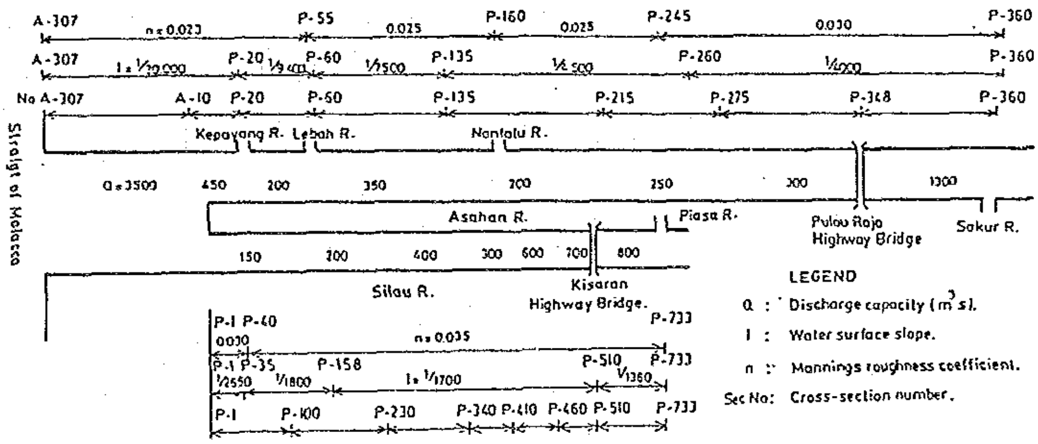
Zone and Reference Point	Area (km²)	Annual Rainfall (mm)	Basin Slope	Topography	Surface Geology	Land Use
Zone - S1	1,050.2	3,000	1/43	Mountain	Weathering Volcanic	Forest
Ⓚ, Kisaran	1,050.2	-	-	and Hill	Rocks and Laterite	
Zone - S2	151.2	2,000	1/1,000	Hill and	Laterite and	Rubber Tree and
Ⓣs, T. Balai	1,201.4	-	-	Alluvial Plain	Alluvial-Deposits	Paddy Field
Zone - A0	3,674.0	-	-	Mountain	Volcanic Ash and	Forest and
Ⓡ, Regulating Dam	3,674.0	1,800	-	and Lake	Weathering Rocks	Paddy Field
Zone - A1	812.3	3,000	1/40	Mountain	Weathering Volcanic	Forest
Ⓟ, Pulau Raja	4,486.3	-	-	and Hill	Rocks and laterite	
Zone - A2	1,215.8	2,000	1/4,000	Hill, Alluvial	Laterite and	Oil Palm and
ⓉA, T. Balai	5,702.1	-	-	Plain and Swamp	Alluvial Deposits	Bush
Ⓣ, T. Balai	6,903.5	-	-	-	-	-
Zone - A3	-	-	-	Estuary	-	-
Ⓜ, River Mouth	-	-	-	-	-	-

Fig. E-5 Flow and Sediment Discharge Capacity of Silau and Asahan River



(a) Plan

(b) Discharge Capacity



(c) Sediment Discharge

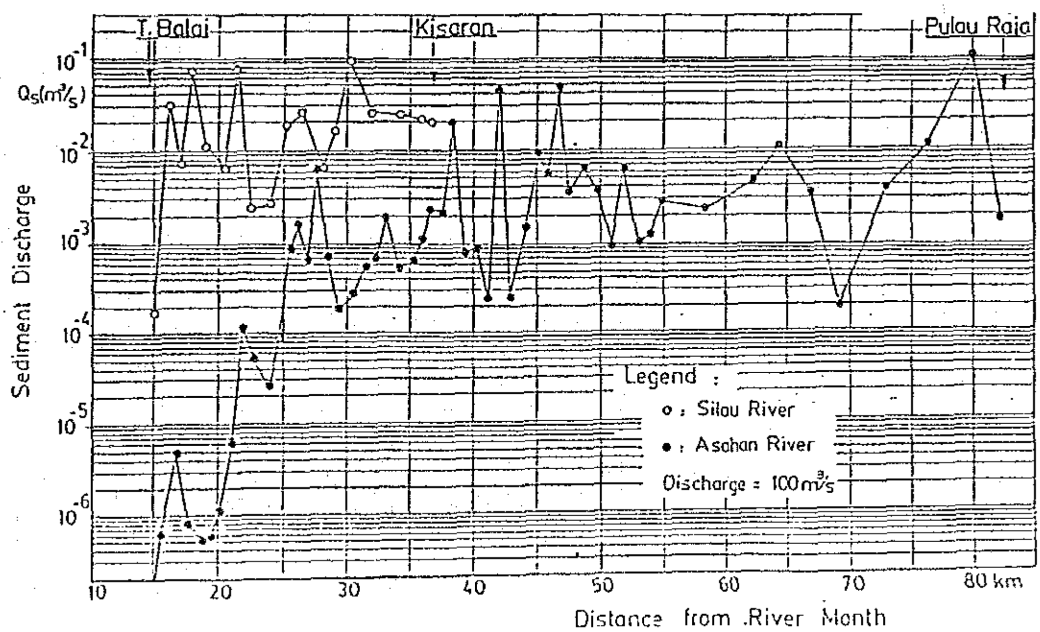
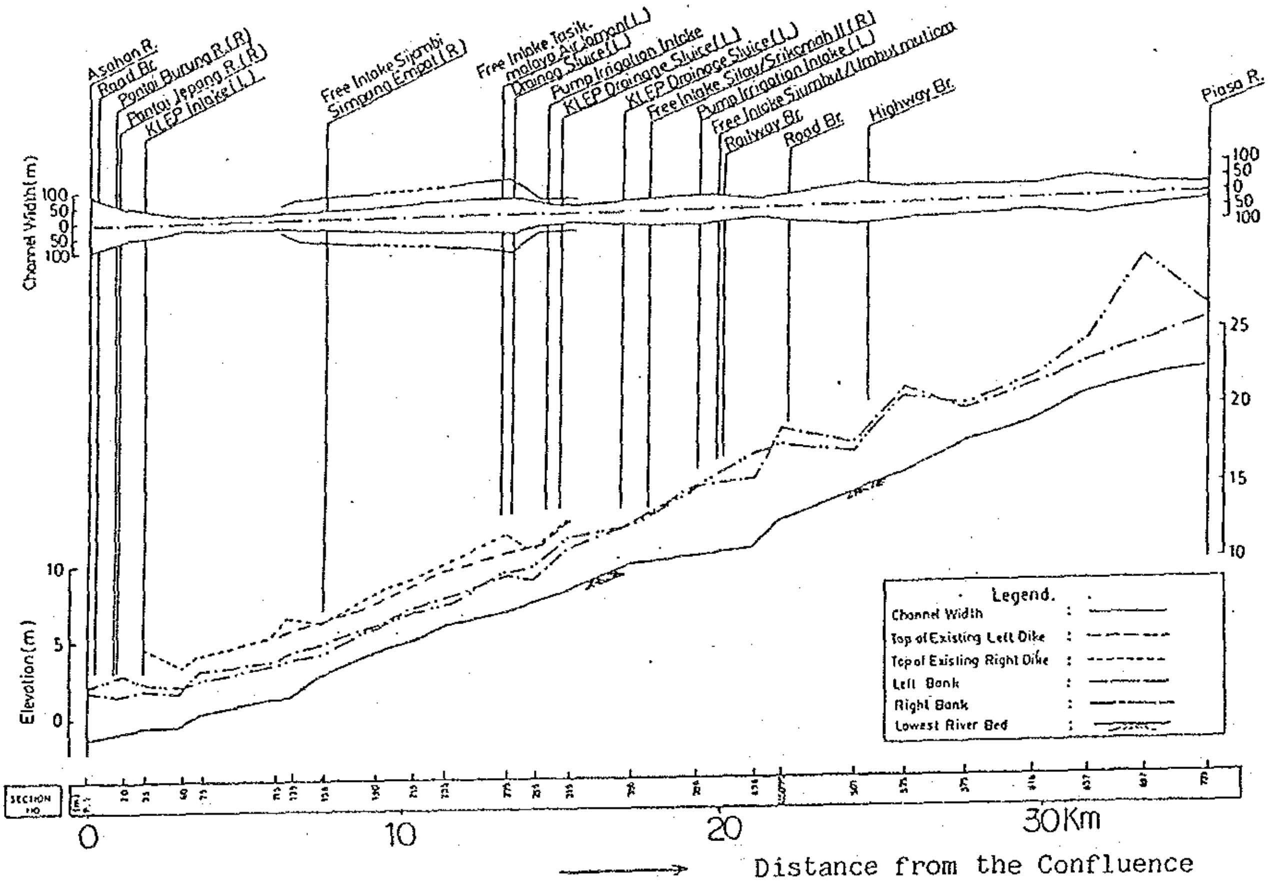


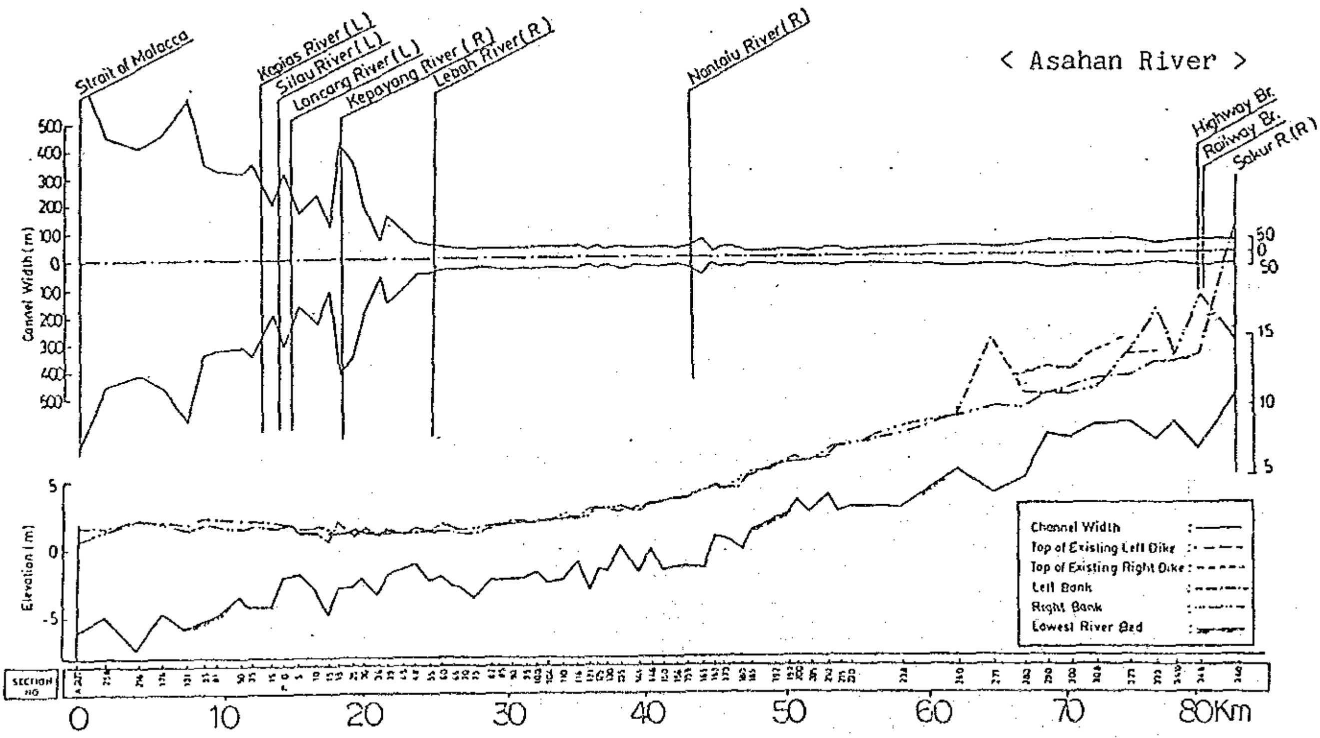
Fig. E-6 Longitudinal Profile of Silau and Asahan River

< Silau River >



Distance from the Confluence Point with Asahan R.

< Asahan River >



Distance from River Mouth

Fig. E-7 Grain Size Distribution of River Bed Materials

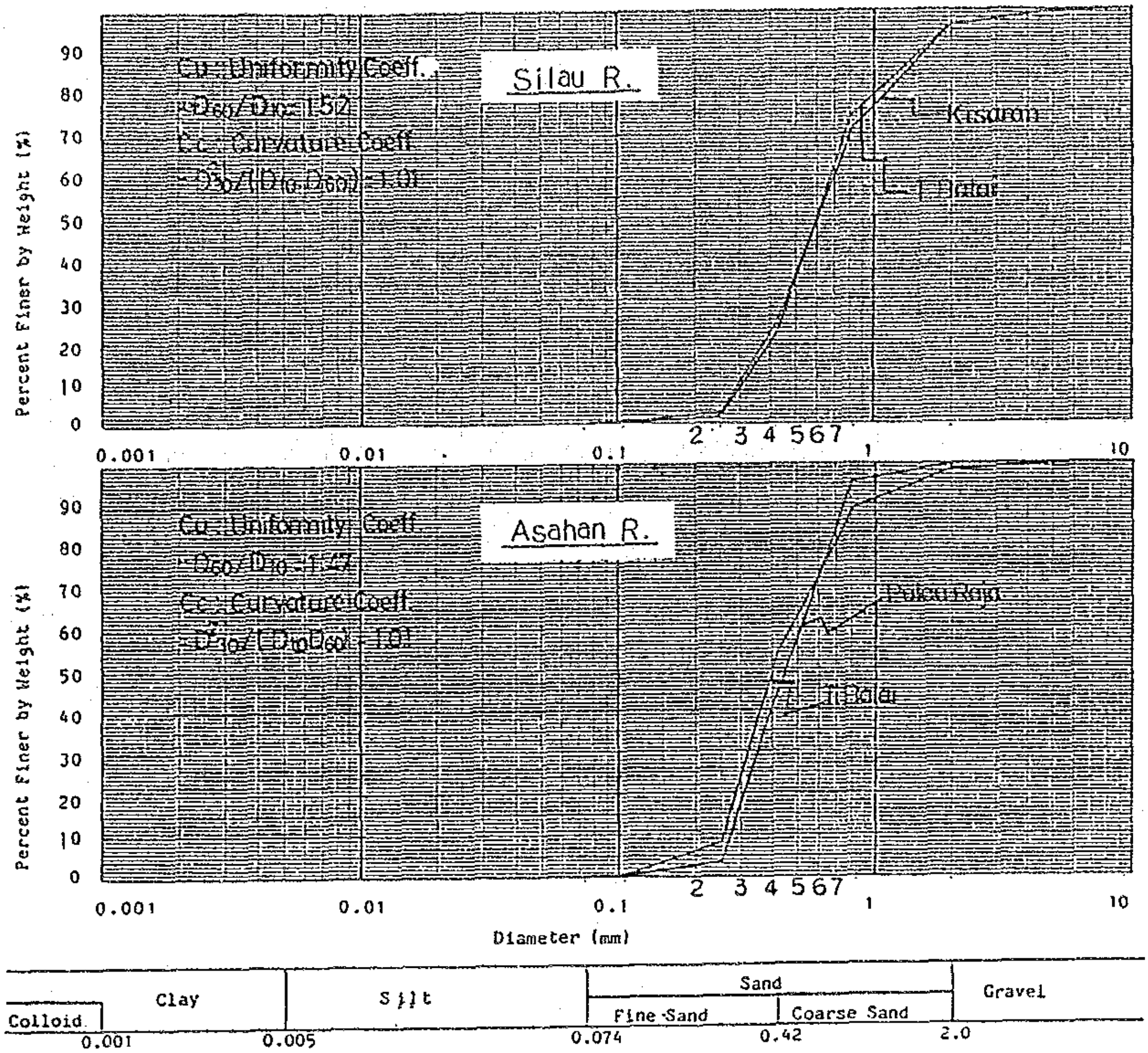
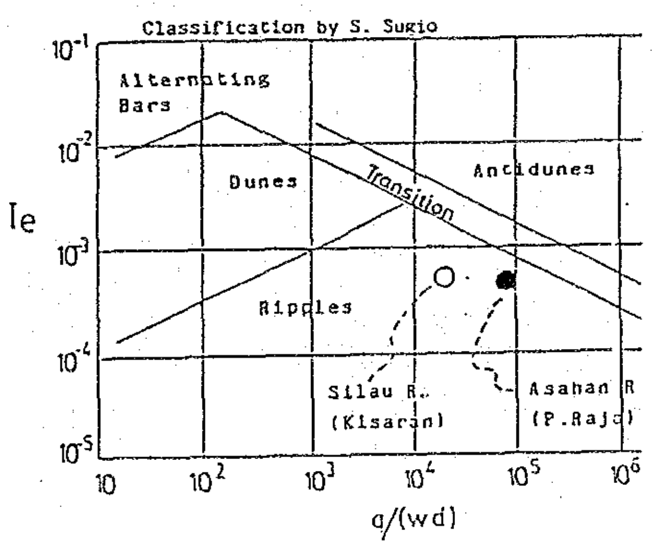


Fig. E-9 Sediment Transportation Regime

Fig. E-8 River Bed Regime



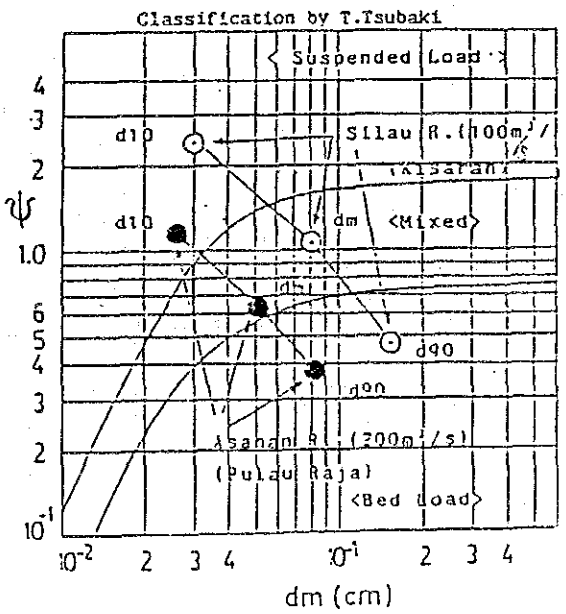
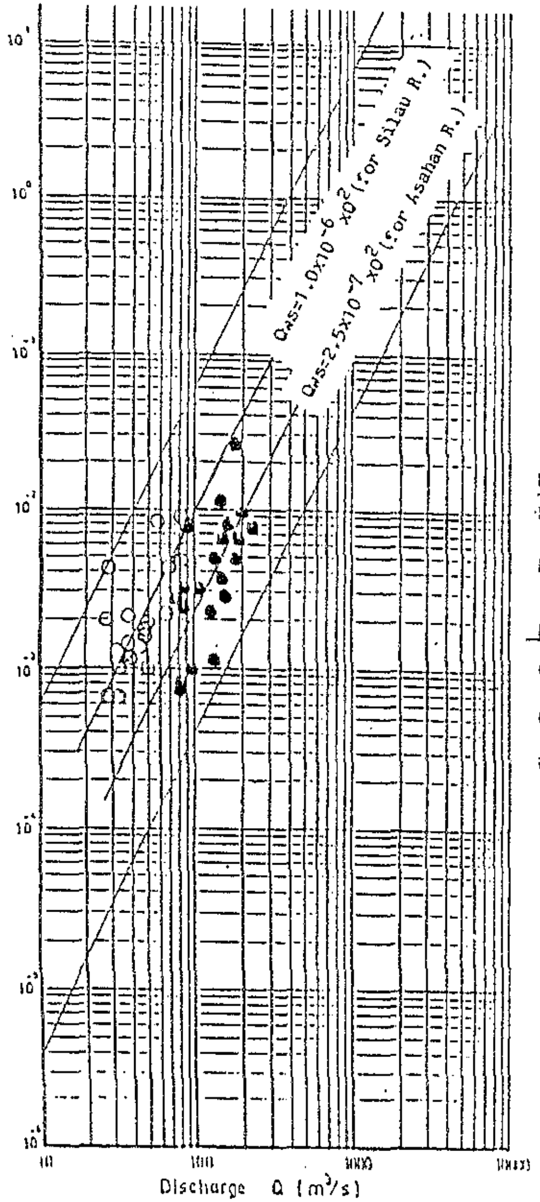


Fig. E-10 Rating Curve for Wash Load



Legend :

- ○ Silau R. (Kisaran)
- ● Asahan R. (Pulau Raja)
- X Kualuh R. (pulo Dogom)

Data used :

Existing : 1978 - 80

Measured by JICA : Dec, 1984

Reference :

Observation Data in Japan

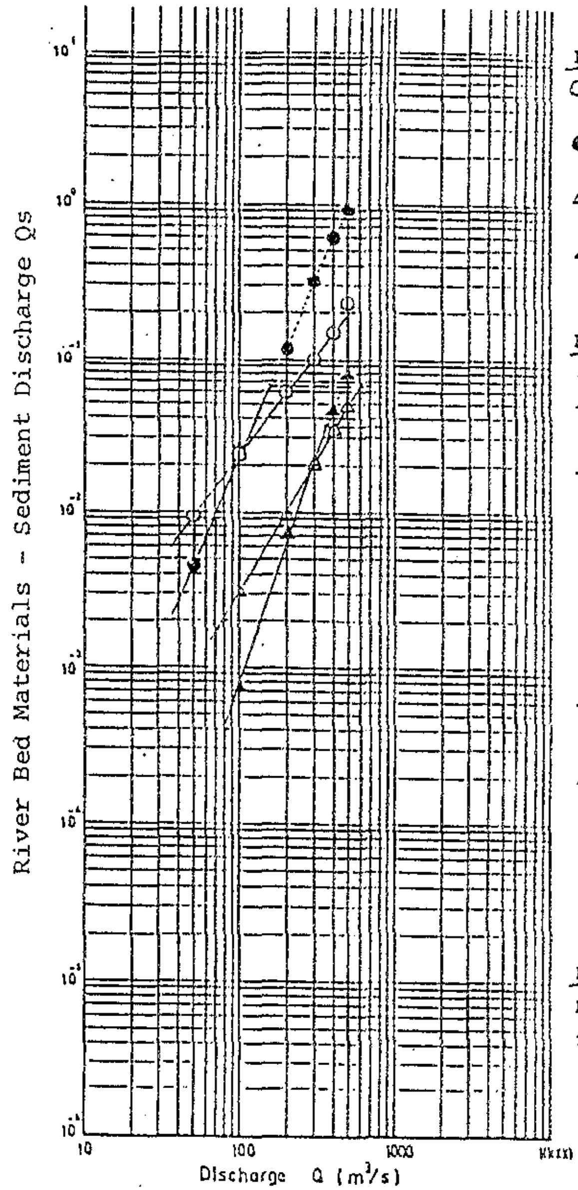
$Q_{ws} = (4 \times 10^{-8} \sim 6 \times 10^{-6}) Q^2$

where,

Q_{ws} : Sediment Discharge of Wash Load (m^3/s)

Q : Flow Discharge (m^3/s)

Fig. E-11 Rating Curve for River Bed Materials



Legend :

- ○ Silau R. (P455-P550) sediment inflow
- ● Silau R. (P10-P35) sediment outflow
- △ Asahan R. (P335-P360) sediment inflow
- ▲ Asahan R. (P60-P90) sediment outflow

Rating Curve :

(Silau R.)

- sediment inflow -

$Qs = 4.867 \times 10^{-5} \times Q^{1.343}$

- sediment outflow -

$Q \leq 150\ m^3/s$:

$Qs = 3.519 \times 10^{-7} \times Q^{2.421}$

$Q > 150\ m^3/s$:

$Qs = 6.527 \times 10^{-2}\ m^3/s$

(Asahan R.)

- sediment inflow -

$Qs = 1.340 \times 10^{-6} \times Q^{1.685}$

- sediment outflow -

$Q \leq 350\ m^3/s$:

$Qs = 5.373 \times 10^{-10} \times Q^{3.073}$

$Q > 350\ m^3/s$:

$Qs = 3.533 \times 10^{-2}\ m^3/s$

Remarks:

Each sediment outflow rating curve is applicable to the present river.

Appendix 2-F

Present Condition of Rivers

Appendix 2-F

PRESENT CONDITIONS OF RIVERS

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1. Present Conditions of Rivers

1.1 River System

The major rivers dissecting the study area are the Bunut river in the northern part, the Asahan and Silau rivers in central part and the Kualuh river in the southern part. A general map of the said river basins is shown in Fig. F-1. The catchment area and distance at major points from the river mouth are shown in Table F-1.

1.2 Characteristics of Rivers

(1) Bunut river

The Bunut river, a big tributary of the Kiri river, has a catchment area of 621 sq.km wit its 59 km length. The Bunut river originates in low hills of about 300 m in elevation, about 25 km southwestward from Kisaran. The river flows northeastward in parallel with the Silau river up to Kisaran. Downstream from Kisaran, the river flows northward through rubber and oil palm estates and paddy field. Afterwards, the river joins the Silau Tua river at Kwala Sikasim and finally joins to the Kiri river near Labuhan Ruku. Downstream from Kisaran, three irrigation intake weirs are constructed and the lands on both banks have been developed for paddy field. To protect the land from flooding the dike of 14 km in total length has been built downstream from Serbangan intake weir.

(2) Asahan river

The Asahan river has a catchment area of 6,863 sq.km including Lake Toba catchment area of 3,674 sq.km, with 150 km length. The Asahan river originates from Lake Toba. The lake has vast natural regulating function by its wide water surface area of 1,100 sq.km. The water level of the lake is being controlled at about El. 905 m by Regulating dam located at 14 km downstream from the outlet of Lake Toba.

The Asahan river flows down northeastward on steep slopes of mountain along deep and narrow valleys up to Bandar Pulau, about 65 km from Lake Toba through Siguragura and Tangga dams for hydropower generation. Downstream from Bandar Pulau, the river flows eastward and the river slope decreases gradually and the surrounding topography changes from hill to plain. The lands on both banks of the river have been developed for rubber and oil-palm estates. At a point about 3 km upstream from highway bridge at Pulau Raja, the river joins the Sakur river.

Downstream from Pulau Raja, the river flows northeastward with meanderings on the alluvial plain. The river slope decreases gradually toward downstream, being 1/4,000 and 1/13,000 respectively in the vicinity of Pulau Raja and Tanjung Balai. The dike of about 11 km in length is built on the right bank to protect the area of Padang Mahondang. In the downstream reaches from Padang Mahondang, the swamp area extends widely to the right bank and partly to the left bank.

At Tanjung Balai, the Asahan river joins the Silau river and finally empties into the Strait of Malacca. Downstream from Tanjung Balai the river widens gradually toward the sea, being 200 m and 1,500 m respectively in the vicinity of Tanjung Balai and the river-mouth.

(3) Silau river

The Silau river, a big tributary of the Asahan river, has a catchment area of 1,180 sq.km with a total length of about 100 km. The river originates on the eastern slope of Mt. Parparean and flows northeastward along steep and narrow valleys. At Samba huta, it joins the Ambalutu river. Downstream from the confluence, the topography changes from hill to plain and the land beside the river has been developed for estates of rubber and oil palm. Afterwards, the river flows eastward and joins the Piasa river at Jati Sari. From Jati Sari to Kisaran, the river flows northward with meanderings on the plain. The river slope decreases gradually toward downstream from 1/800 to 1/1,500. In the downstream reaches from Kisaran, the river flows eastward and finally joins to the Asahan river at Tanjung Balai. In this stretch, there are some irrigation intakes and drainage outlets. The lands on both banks of the river have been developed for paddy field. The continuous dike has been built on both banks to protect the land from floodings.

(4) Kualuh river

The Kualuh river has a catchment area of 3,820 sq.km of wide area with its total length of 165 km. The Kualuh river originates on the northeastern slope of Mt. Sihabuhabu and flows northeastward along steep and narrow valleys. Near Pulo Dogom, the river joins the Harimau river. Downstream from Pulo Dogom, the river flows eastward and the surrounding topography changes from hill to plain. The river slope decreases gradually toward downstream. At Kuala Tani, the river joins the Natas river. In the stretch between Pulo Dogom and the confluence of the Natas river, estates of rubber and oil palm and paddy field extend to both banks of the river. To protect the paddy field, the dike has been built on the left bank in the downstream reaches of highway bridge. Afterwards, the river flows with meanderings on the alluvial plain and joins the Kanopan river at Teluk Binjai and the Kuo river at Kuala Bangka. The swamp area extends widely to the right bank downstream from the confluence of the Natas river and the left bank downstream from the confluence of the Kanopan river. Afterwards, the Kualuh river flows northward and finally empties into the Strait of Malacca at Tanjung Leidong. Downstream from the confluence of the Kuo river, the Kualuh river widens gradually toward the sea, being 200 m and 4,000 m respectively in the vicinity of Kualuh Bangka and the estuary.

1.3 Cross-Sections and Longitudinal Profiles of River Channels

The existing survey results on cross-sections of the river channels are collected and those are listed in Table F-2. In order to check the collected survey results and to obtain additional cross-sections, check and supplemental survey were carried out by the Study Team during the period from November 1984 to July 1985. The items and quantity of the survey are listed in Table F-3, and the survey location is shown in Fig. F-2.

Based on the surveyed cross-sections of river channel, the longitudinal profiles of the rivers are prepared as shown in Fig. F-3 and the cross-sections are compiled in Data Book.

1.4 Discharge Capacity of River Channels

The discharge capacity of the existing river channel are estimated based on water level calculation by the nonuniform flow method with regard to the Bunut, Asahan, Silau, Kualuh and Kanopan rivers. In the calculation, the values of Manning's roughness coefficient shown in Table F-4 are applied in this study considering the existing channel conditions.

The estimated discharge capacities are shown in Table F-5 and Fig. F-4. From the figure, the following facts are revealed:

(1) Bunut river

(a) The channel upstream from highway bridge at Bunut has comparatively high discharge capacity more than 80 m^3/sec.

(b) Downstream from the bridge, the capacity decrease to 70 m^3/sec near the confluence with the Beluru river.

(c) Downstream from the confluence with Silau Tua river, the capacities increase toward the river-mouth of the Kiri river from 130 to 500 m^3/sec.

(2) Asahan river

(a) The channel upstream from highway bridge at Pulau Raja has comparatively high discharge capacity of 1,300 m^3/sec.

(b) Downstream from the bridge, the discharge capacities decrease gradually toward downstream. Near the confluence of the Nantalu river, the capacity decreases to extremely low value of 200 m^3/sec.

(c) Downstream from the confluence of the Lebah river, the capacities increase toward the river-mouth from 100 to 3,500 m^3/sec.

(3) Silau river

(a) The channel upstream from Kisaran has comparatively high discharge capacity more than 950 m^3/sec.

(b) In the vicinity of Kisaran, the capacity is 700 m^3/sec. Downstream from Kisaran, the capacity decreases from 600 to only 150 m^3/sec.

(4) Kualuh river

(a) The channel upstream from highway bridge at Gunting Saga has comparatively high discharge capacity of 1,100 m^3/sec.

(b) Downstream from the bridge, the capacities decrease gradually toward downstream. Near the confluence with the Pamengke river, the capacity decreases to low of 200 m^3/sec.

(c) Downstream from the confluence, the capacities increase toward the river-mouth from 350 to 1,500 m^3/sec.

(d) The discharge capacities of the downstream reaches of the Kanopan river are from 50 to 100 m^3/sec.

2. River Facilities

2.1 River dikes

In the study area, the river dikes of 86 km in total length have been constructed in the middle and lower reaches. The dike length for each river is as follows:

River	Dike Length (km)		
	Mainstream	Tributary	Total
Bunut river	14	-	14
Silau river	28	-	28
Asahan river	11	4	15
Kualuh river	22	7	29
Total	75	11	86

The location of these existing dikes is shown in Fig. F-5. Almost all the dikes are constructed in the form of cross-section with crown width of 2.0 to 3.5 m, side slope of 1:1 to 1:2 and height of 1 to 4 m as illustrated in Fig. F-6. River improvement and rehabilitation works during 1982 to 1984 are listed in Table F-6.

The stability of existing dike body is examined using the formula of seepage line, because the existing dikes were constructed close to the stream course and the stability of dike body seems insufficient against percolation during high-water period. The formula and criteria applied are as follows:

$$L = c \times (k \times h \times t/e)^{1/2} \qquad \text{Eq.(F.1)}$$

where,

L	:	Creep distance (m)
c	:	Constant (2.0 m/hr)
k	:	Coefficient of permeability
e	:	Void ratio of dike body
h	:	Mean water depth (m)
t	:	Duration of high water (hr)

In this equation, dike body is defined as stable when the calculated creep distance is smaller than the allowable distance.

The assumed condition and the result of calculation are shown in Table F-5. From the table, it is preliminary concluded that the existing dikes are generally not stable against permeability, except some dikes which has smaller permeability coefficient than 0.03.

2.2 Bridge, drainage outlets and intakes

The river facilities such as bridge, drainage outlet, intake exist along the river courses. The location and dimension of bridges are listed in Table F-8 and the profiles of major bridges are shown in Fig. F-7. The dimension of drainage outlets and irrigation intakes are prepared in Table F-9 and the profiles of intakes are shown in Fig. F-8.

Table F-1 Catchment Area and Distance of Major Points from River-mouth

River	Point	Catchment area (Km2)	Distance (Km)
Bunut river			
Mainstream	Highway Br.	115	25
Mainstream	Confluence of Silau Tua River	292	4
Silau Tua river	Confluence to Bunut river	323	4
Mainstream	Confluence to Kiri river	621	0
Asahan River			
Mainstream	Outlet of Lake Toba	-	152
Mainstream	Regulating dam	3,674	135
Mainstream	Sigura-gura dam	-	130
Mainstream	Tangga Dam	3,820	125
Mainstream	No.3 dam site (under planning)	3.888	117
Mainstream	Confluence of Sakur river	4,160	80
Sakur river	Confluence to Mainstream	311	-
Mainstream	Pulau Raja	4,471	77
Mainstream	Simpang Empat	4,727	41
Mainstream	Confluence of Silau river	5,101	15
Mainstream	River-mouth	6,284	0
Silau river			
Mainstream	Confluence of Piasa river	659	36
Piasa river	Confluence to Silau river	330	-
Mainstream	Kisaran	1,036	23
Mainstream	Confluence to Asahan river	1,183	0
Kualuh river			
Mainstream	Pulo dogom	1,116	117
Mainstream	Highway Br.	1,171	102
Mainstream	Confluence of Natas river	2,090	81
Natas river	Confluence to Kualuh river	515	-
Mainstream	Confluence of Kanopan river	2,623	56
Mainstream	Rivermounth	3,815	0

Table F.2 List of Existing Survey Results on Plan, Profile and Cross-section of River Channel

River	Survey Year	Surveyed Stretch	Kind of Survey	Scale	Survey Company
Asahan River	1982	River-mouth Confluence of Silau River Length: 15.8 km (Ave. interval of C-section: 50 m)	Plan Profile Cross-section	1/2,000 V: 1/200, H: 1/2,000 V: 1/200, H: 1/400	PT. Yarmaya
	-	Confluence of Silau River Confluence of Tarum River Length: 69.5 km (Ave. interval of C-section: 200 m)	Plan Profile Cross-section	15,000 V: 1/200, H: 1/5,000 V: 1/200, H: 1/500	PT. Esconsoil
	1982	Upstream from Confluence of Tarum River Length: 12.8 km (Ave. interval of C-section: 50 m)	Plan Profile Cross-section	1/2,000 V: 1/200, H: 1/2,000 V: 1/200, H: 1/400	PT. Yaramaya
Silau River	1981	Confluence of Asahan River Confluence of Plasa River Length: 20.5 km (Ave. interval of C-section: 50 m)	Plan Profile Cross-section	1/2,000 V: 1/200, H:1/2,000 1/200	PT. Nusantara Survey

Table F.3 List of River Survey by JICA Study Team (1/2)

Kind of Survey	River	Stretch	Quantity	Interval (Ave)
Checking Survey				
1. Bench Mark Leveling	-	INALUM B.M - Kisaran B.M	82 km	-
2. Bench Mark Setting	Asahan	Rivermouth - Confluence of Sakur R.	67	1.2 km
	Silau	Tg. Balai - Confluence of Piasa R.	25	1.4 km
3. Profile Leveling	Asahan	Rivermouth - Confluence of Sakur R.	82 km	-
	Silau	Tg. Balai - Confluence of Piasa R.	35 km	-
4. Longitudinal River Water Level Survey	Asahan	Rivermouth - Confluence of Sakur R.	67 points	1.2 km
	Silau	Tg. Balai - Confluence of Piasa R.	25 points	1.4 km
5. Cross-section Leveling	Asahan	Rivermouth - Confluence of Sakur R.	67 sections	1.2 km
	Silau	Tg. Balai - Confluence of Piasa R.	25 sections	1.4 km
Supplemental Survey				
1. Bench Mark Leveling	-	Pulau Raja B.M - Aek Kanopan B.M	18 km	-
		Sungai Bajangkar B.M - Tg. Tiram B.M	18 km	-
		Aek Kanopan B.M - Teluk Binjai B.M	35 km	-
		Nantalu R.(MBK7)- Leidong R.(Air hitam)	15 km	-
2. Bench Mark Setting	Kualuh	Rivermouth - Highway Br.	42	2.4 km
	Bunut	Rivermouth - Bunut	25	1.8 km
	Nantalu	Confluence of Asahan R.-10 km upstream point	4	3.3 km
	Lebah	Confluence of Asahan R.-14 km upstream point	3	7.0 km
	Kanopan	Teluk Binjai - Pernangkaan	5	1.8 km

Table F.3 List of River Survey by JICA Study Team (2/2)

Kind of Survey	River	Stretch	Quantity	Interval (Ave)
3. Profile Leveling	Kualuh	Rivermouth - Highway Br.	100 km	-
	Bunut	Rivermouth - Bunut	44 km	-
	Nantalu	Confluence of Asahan R.-10 km upstream point	10 km	-
	Lebah	Confluence of Asahan R.-14 km upstream point	14 km	
	Kanopan	Teluk Binjai - Pernangkaan	7 km	-
4. Longitudinal River Water Level Survey	Kualuh	Rivermouth - Highway Br.	42 points	2.4 km
	Bunut	Rivermouth - Bunut	25 points	1.8 km
	Nantalu	Confluence of Asahan R.-10 km upstream point	4 points	3.3 km
5. Cross section Leveling	Kualuh	Rivermouth - Highway Br.	42 sections	2.4 km
	Bunut	Rivermouth - Binut	25 sections	1.8 km
	Nantalu	Confluence of Asahan R.-10 km upstream point	4 sections	3.3 km
	Lebah	Confluence of Asahan R.-14 km upstream point	3 sections	7.0 km
	Kanopan	Teluk Binjai - Pernangkaan	5 sections	1.8 km

Table F-4 Manning's Roughness Coefficient under Existing Channel Conditions applied for Calculation of Discharge Capacity

Channel stretch		Manning's n
1. Bunut River		
River-mouth	- B 8 (0.1 km downstream from Balai river)	0.025
B 8 - B 17	(0.5 km downstream from Panca Arga Intake)	0.030
B 17 - B 26	(Highway bridge)	0.035
2. Asahan River		
River-mouth	- P 55 (0.4 km downstream from Lebah river)	0.023
P 55	- P 160 (0.3 km downstream from Nantalu river)	0.025
P 160	- P 245 (16.4 km upstream from Nantalu river)	0.028
P 245	- P 360 (Tarum river)	0.030
3. Silau River		
Asahan river	- P 40 (2.75 km upstream from Bandar Jepang river)	0.030
P 40	- P 510 (Highway bridge at Kisaran)	0.035
4. Kualuh River		
River-mouth	- K 19 (0.5 km upstream from Kanopan river)	0.025
K 19 - K 31	(0.5 km upstream from Nantalu river)	0.028
K 31 - K 42	(Highway bridge)	0.030
5. Kanopan River		
Kualuh river	- KP 3 (5.4 km downstream from Road bridge)	0.028
KP 3 - KP 5	(8.2 km upstream from Road bridge)	0.035

Table F-5 Estimated Discharge Capacity of Existing Channel (1/2)

	Channel stretch		Discharge Capacity (cms)
1.	Bunut River (including a part of the Kiri river)		
	River-mouth	- B 4 (0.9 km upstream of Road Br.)	500
	B 4 - B 6	(3.2 km downstream of Balai R.)	300
	B 6 - B 10	(3.3 km upstream of Balai R.)	200
	B 10 - B 12	(1.9 km upstream of Silau Tua R.)	130
	B 12 - B 18	(1.1 km upstream of Panca Arga Intake)	70
	B 18 - B 22	(0.6 km upstream of Serbangan Intake).	70
	B 22 - B 26	(Highway Br.)	80
2.	Asahan River		
	River-mouth	- A 10 (0.4 km upstream from Silau river)	3500
	A 10	- P 20 (0.2 km downstream from Kepayang river)	450
	P 20	- P 60 (0.6 km km upstream from Lebah river)	200
	P 60	- P 135 (5 km downstream from Nantalu river)	350
	P 135	- P 215 (10.6 km upstream from Nantalu river)	200
	P 215	- P 275 (14.5 km downstream from Highway bridge at Pulau Raja)	250
	P 275	- P 348 (Highway bridge)	350
	P 348	- P 360 (Confluence of Sakur river)	1300

Table F-5 Estimated Discharge Capacity of Existing channel (2/2)

Channel stretch		Discharge Capacity (cms)
3. Silau River		
Asahan river	- P 100 (5.7 km downstream from Free intake, Sijambi/Simpang Empat)	150
P 100	- P 230 (4.1 km downstream from Free intake, Tasikmalaya/Air Joman)	200
P 230	- P 340 (2.6 km downstream from Free intake, Silau/Srikamah II)	400
P 340	- P 410 (0.9 km downstream from Railway bridge)	300
P 410	- P 460 (0.2 km upstream from Kisaran road bridge)	600
P 460	- P 510 (near highway bridge)	700
P 510	- P 733 (Confluence of Piasa river)	950
4. Kualuh River		
River-mouth	- K 11 (5.9 km downstream of Kuo R.)	1500
K 11 - K 18	(1.5 km downstream of Kanopan R.)	1100
K 18 - K 22	(5.6 km upstream of Kanopan R.)	350
K 22 - K 26	(2.9 km upstream of Pamengke R.)	200
K 26 - K 29	(0.4 km upstream of Sidari R.)	350
K 29 - K 36	(6.6 km upstream of Simangalam R.)	300
K 36 - K 39	(5.5 km downstream of Highway Br.)	350
K 39 - K 42	(Highway Br.)	500
5. Kanopan River		
Kualuh river	- KP 2 (4.1 km upstream from Kualuh river)	100
KP 2 - KP 4	(Road bridge)	90
KP 4 - KP 5	(8.2 km upstream from Road bridge)	50

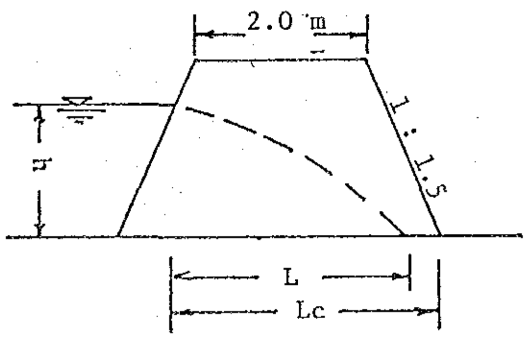
Table F.6 River Improvement Works (1982 - 1984)

Site	Year	Location	Budget (million Rp.)	Remarks
A. Asahan River				
1. Kec. Pulau Rakyat	1982	P 310 - 255 P 260	100.0	Reconstruction of broken Dike (82 Apr. Flood) Lining of river channel L = 0.415 km
2. Kec. Pulau Rakyat	1984	P 322 - 309 P 323 - 324	50.0	Heightening L = 1.75 km and New Dike L = 0.55 km
3. Kec. Pulau Rakyat	1984	P 276 - 275 P 323 - 322	50.0	Reconstruction of broken Dike L = 46 m and New Dike L = 0.31 km (including drainage canal L = 2.1 km)
4. Kec. Pulau Rakyat	1984	P 321 - 278	50.0	Reconstruction of broken Dike L = 62 m Rehabilitation of slidden Dike L = 1.66 km
5. Kec. Pulau Rakyat	1984	P 276 - 275	19.84	Reconstruction of broken Dike L = 22 m
B. Silau River				
1. Kec. Air Joman	1983	P 155 - 165	251.1	Rehabilitation (R); L = 605 m (L):L = 598 m
2. Kec. Simpan Empat	1984	P 155	258.8	Heightening (R); L = 1.00 km (L): L = 1.00 km

Note : Collected from DPUP,North Sumatra

Table F-7 Creeping Distance of Existing Dike

Item	Case 1	Case 2	Case 3
1. Coefficient of permeability (k=0.2 m/hr)			
- Void ratio of dike	0.5	1.0	1.5
- Mean water depth (m)	1.4	1.4	1.4
- Duration of flood (hr)	48	48	48
- Creep distance of seepage line (m)	10.4	7.3	6.0
- Allowable creep distance (m)	5.0	5.0	5.0
2. Coefficient of permeability (k=0.1 m/hr)			
- Void ratio of dike	0.5	1.0	1.5
- Mean water depth (m)	1.4	1.4	1.4
- Duration of flood (hr)	48	48	48
- Creep distance of seepage line (m)	7.3	5.2	4.2
- Allowable creep distance (m)	5.0	5.0	5.0
3. Coefficient of permeability (k=0.03 m/hr)			
- Void ratio of dike	0.5	1.0	1.5
- Mean water depth (m)	1.4	1.4	1.4
- Duration of flood (hr)	48	48	48
- Creep distance of seepage line (m)	4.0	2.8	2.3
- Allowable creep distance (m)	5.0	5.0	5.0



Formula applied:

$$L = C(k.h.t/e)^{1/2}$$

where,
- L: Creep distance of seepage line (m)
- C: Constant (2.0 m/hr)
- k: Coefficient of permeability
- e: Void ratio of dike body
- h: Meam water depth (m)
- t: Duration of flood (hr)

Table F.8 Dimension of Main Bridge

Name of Bridge	Location	Elevation of Road-face	Length (m)	Width (m)	Data Source	Remarks
1. Asahan R						
- Asahan Br.	P-346		28.0+33.6 +28.0 =89.6	1.0+6.0 +1.0	Bina Marga	Highway
- (Kapias kiri Br.)	Kapias.K.R.		42.3	0.65+4.0+0.65	DPUP	
- (Selat Lancang Br.)	S.Lancang R.		69.4	3.65	Site Survey	
2. Silau R.						
- Muara Silau Br.	P-3		7.5+10.5+10x 11.0+9.0=137.0	1.0+5.4 +1.0	DPUP	Reconstruction Plan is under Consideration
- Silau Br.	P-510	22.552	2(20.0+28.0) +33.6=129.6	1.0+7.0 + 1.0	Bina Marga	Highway
- Silau Br.	P-460	19.045		4.0	Bina Marga	
- (Bandar Jepang Br.)	B.Jepang R.		19.20	3.20	Site Survey	

DPUP : Dinas P.U. Propinsi Dati I Sumatera Utara, Seksi Asahan

Table F.9 Existing Intakes along Asahan and Silau River

Description	Location	Width (m)	Remarks
1. Asahan River			
Padang Mahondang	P - 295 (R)	1.3 x 2	with gate
2. Silau River			
KLEP Intake	P - 33 (L)	5.0	
Intake/Sijambi	P - 156 (R)	0.6 + 1.0 + 0.8	with gate
Intake/Tasik Malaya	P - 268 (L)	1.2 x 4	with gate
Drainage Sluice	P - 278 (L)	1.0 x 2	with gate
Pump Irrigation Intake	P - 301 (L)	0 300 x 21.5 HP x 2	not used since 1981
KLEP Drainage Sluice	P - 308 (L)	1.5	with gate
KLEP Drainage Sluice	P - 347 (L)	0 800	with gate
Intake/Srikamah II	P - 363 (R)	1.3 x 3	with gate
Pump Irrigation Intake	P - 395 (L)		not used since 1982
Intake/Siumbut-umbut	P - 408 (L)	1.2 x 3	

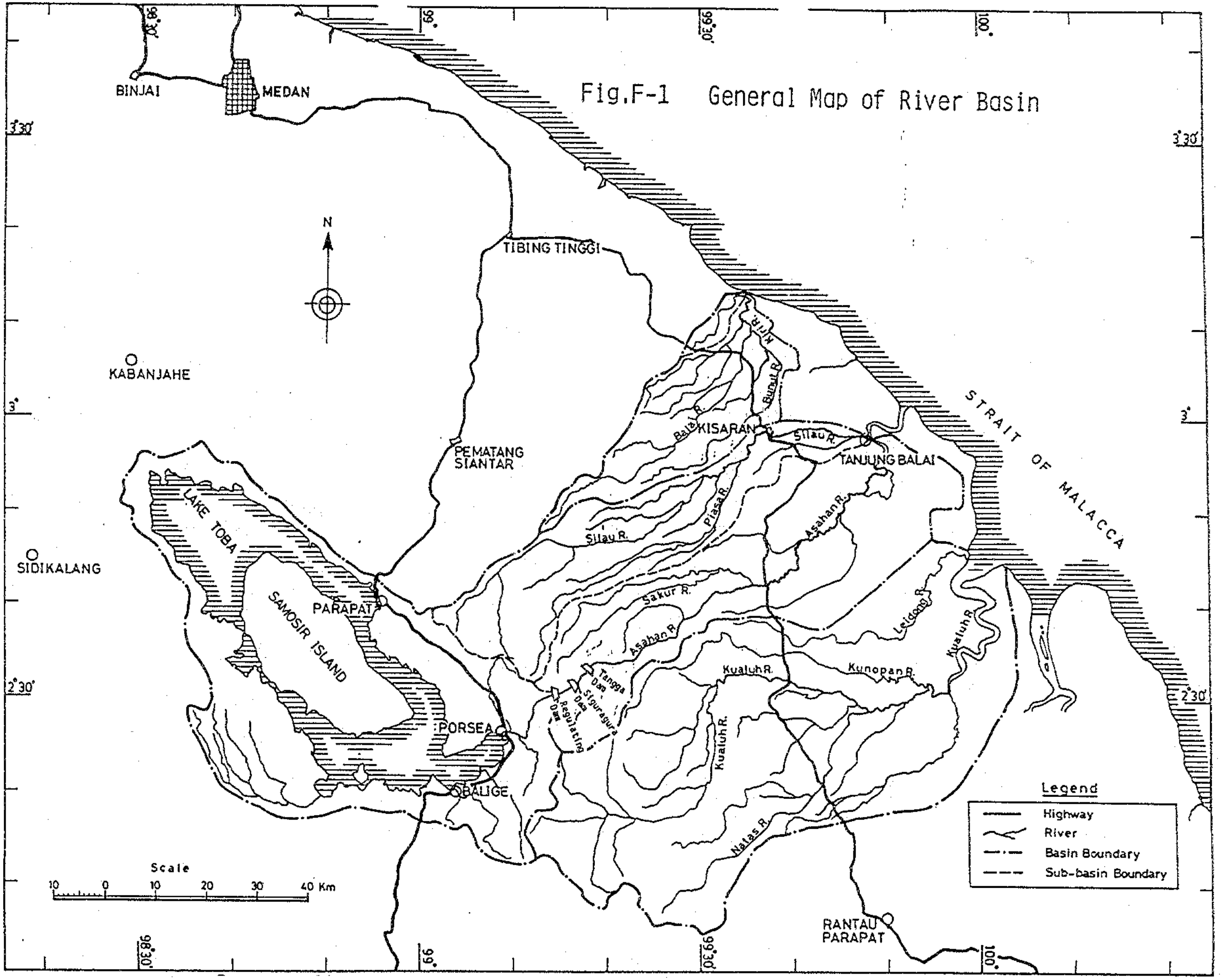


Fig.F-1 General Map of River Basin

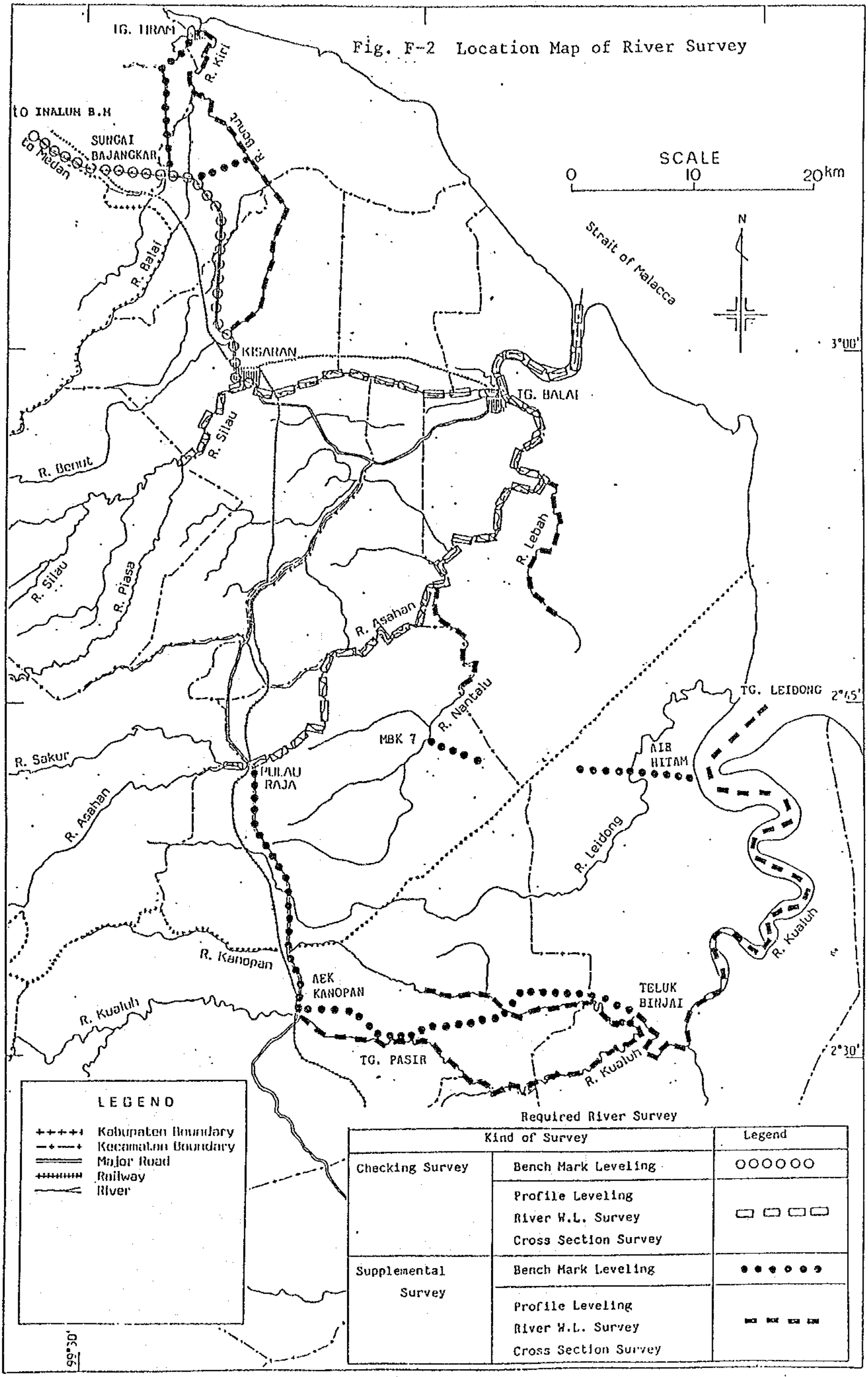


Fig. F-2 Location Map of River Survey
SCALE
0
10
20km
N
Strait of Malacca
3°00'
2°45'
2°30'
99°30'
TG. TIRAM
R. Kiri
TO INALUM B.H
SUNGAI BAJANGKAR
to Medan
R. Benut
R. Balai
KISARAN
TG. BALAI
R. Silau
R. Benut
R. Lebah
R. Silau
R. Piasa
R. Asahan
R. Nantalu
MBK 7
TG. LEIDONG
AIR HITAM
R. Sakur
PULAU RAJA
R. Asahan
R. Leidong
R. Kualuh
R. Kanopan
AEK KANOPAN
TELUK BINJAI
R. Kualuh
TG. PASIR
R. Kualuh
LEGEND
Kobupaten Boundary
Kecamatan Boundary
Major Road
Railway
River
Required River Survey
Kind of Survey
Legend
Checking Survey
Bench Mark Leveling
OOOOOO
Profile Leveling
River W.L. Survey
Cross Section Survey
Supplemental Survey
Bench Mark Leveling
Profile Leveling
River W.L. Survey
Cross Section Survey

Fig. F-3 River Profile (1/4)

Bunut River

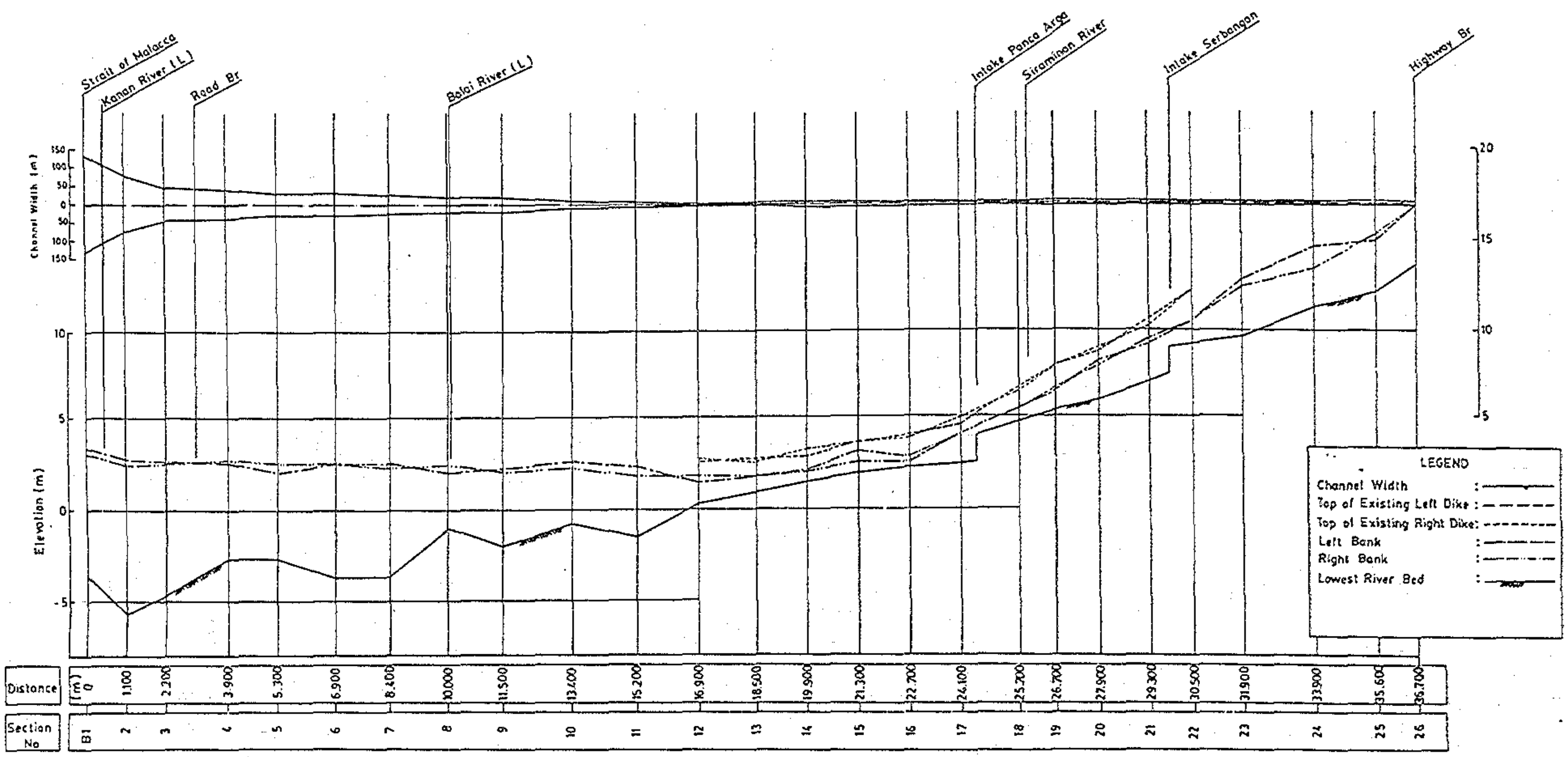


Fig.F-3 River Profile (2/4)
Asahan River

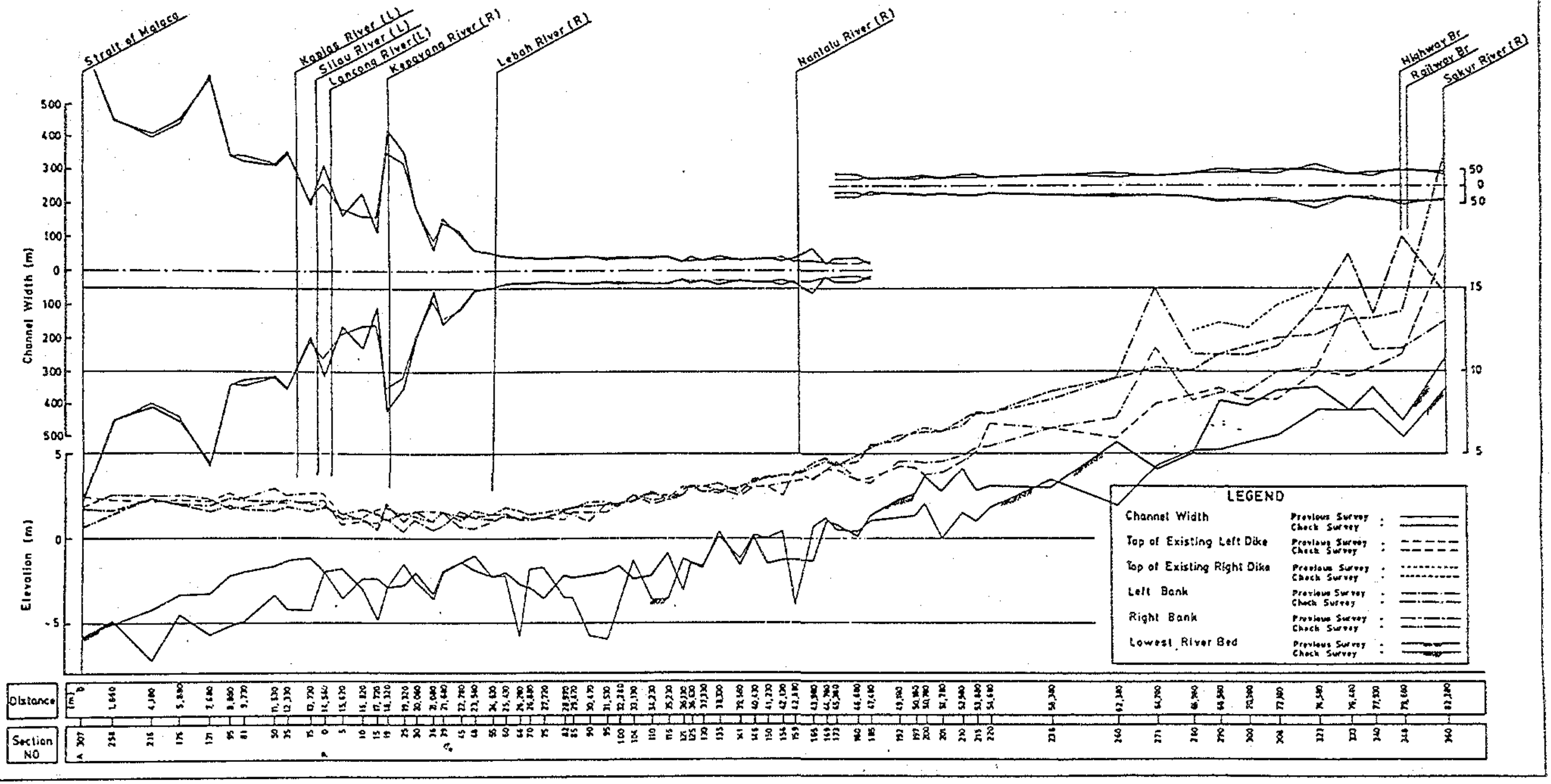


Fig.F-3 River Profile (3/4)
Silau River

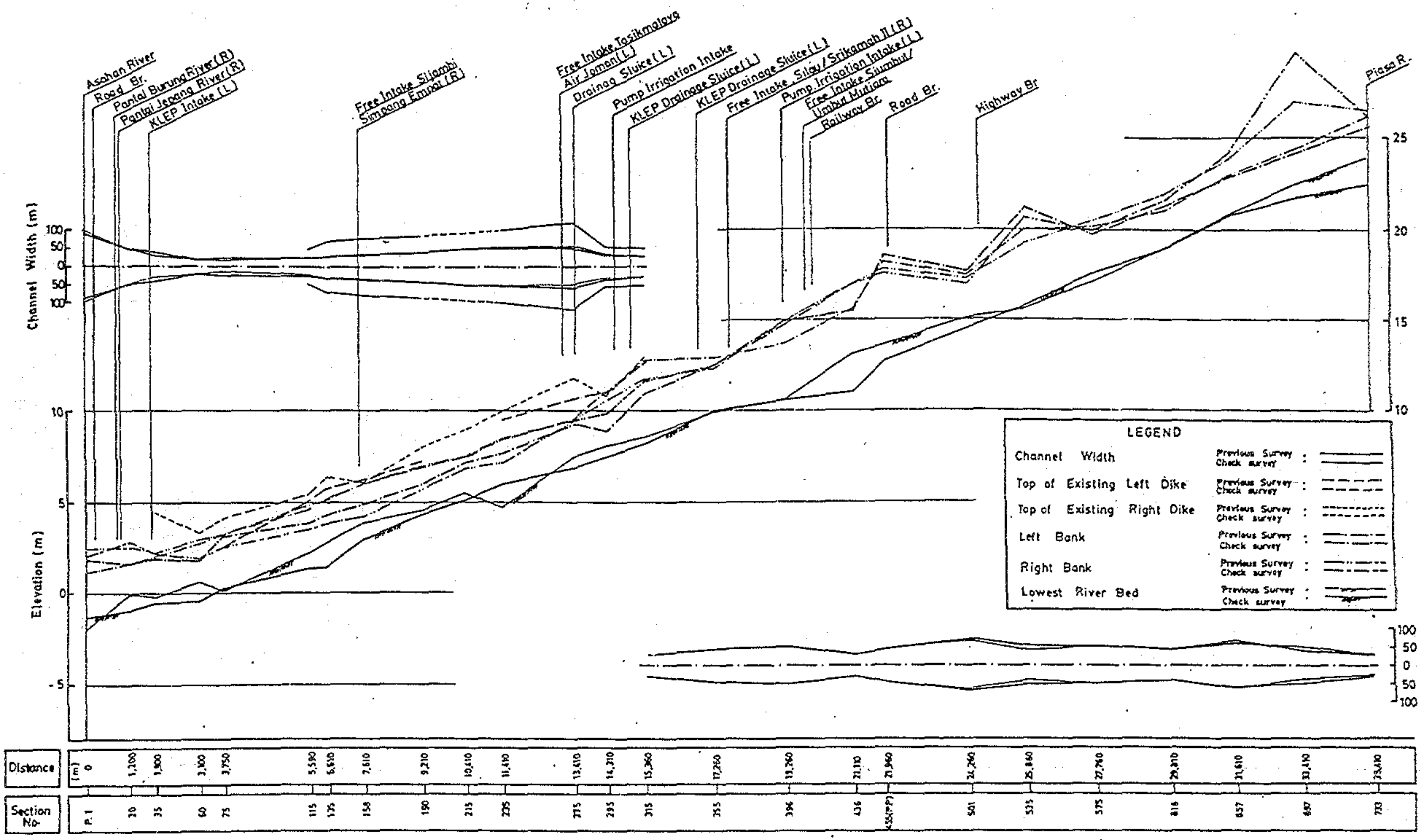


Fig. F-3 River Profile (4/4)

Kualuh River

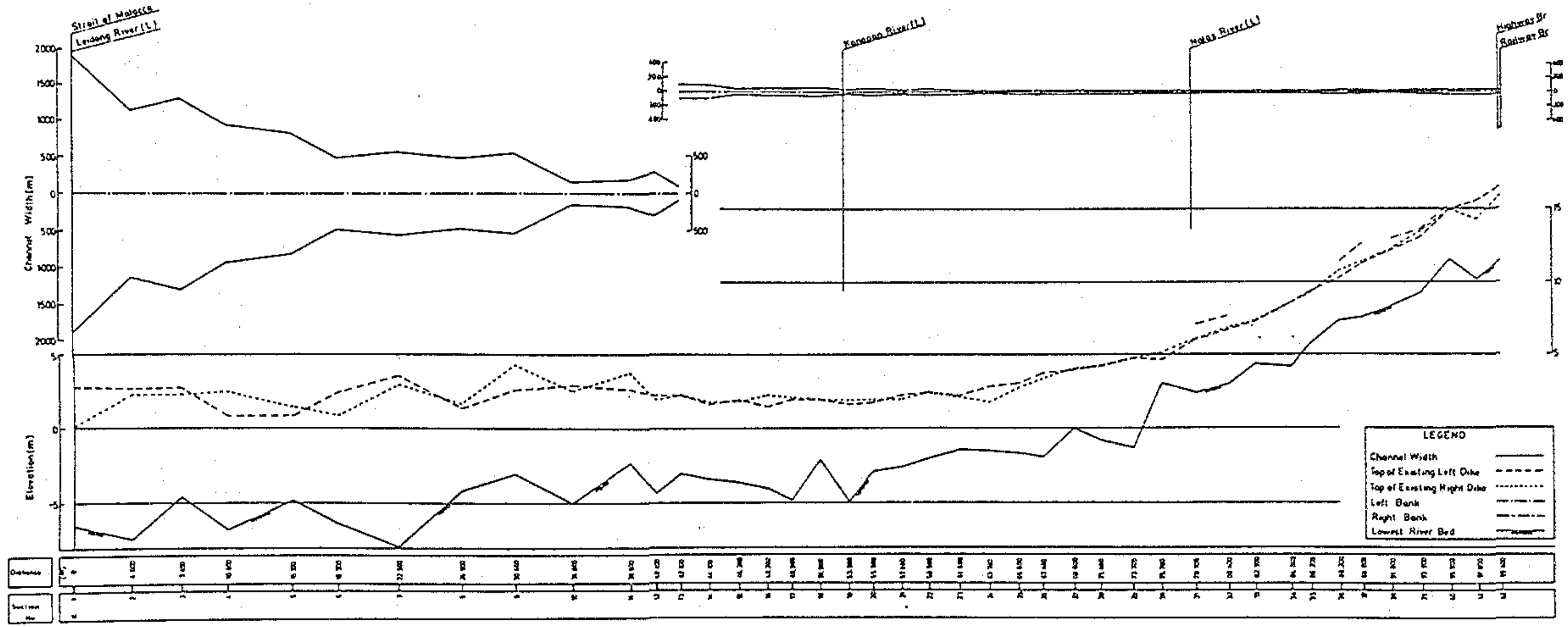


Fig. F-4 Discharge Capacity of Existing River Channel

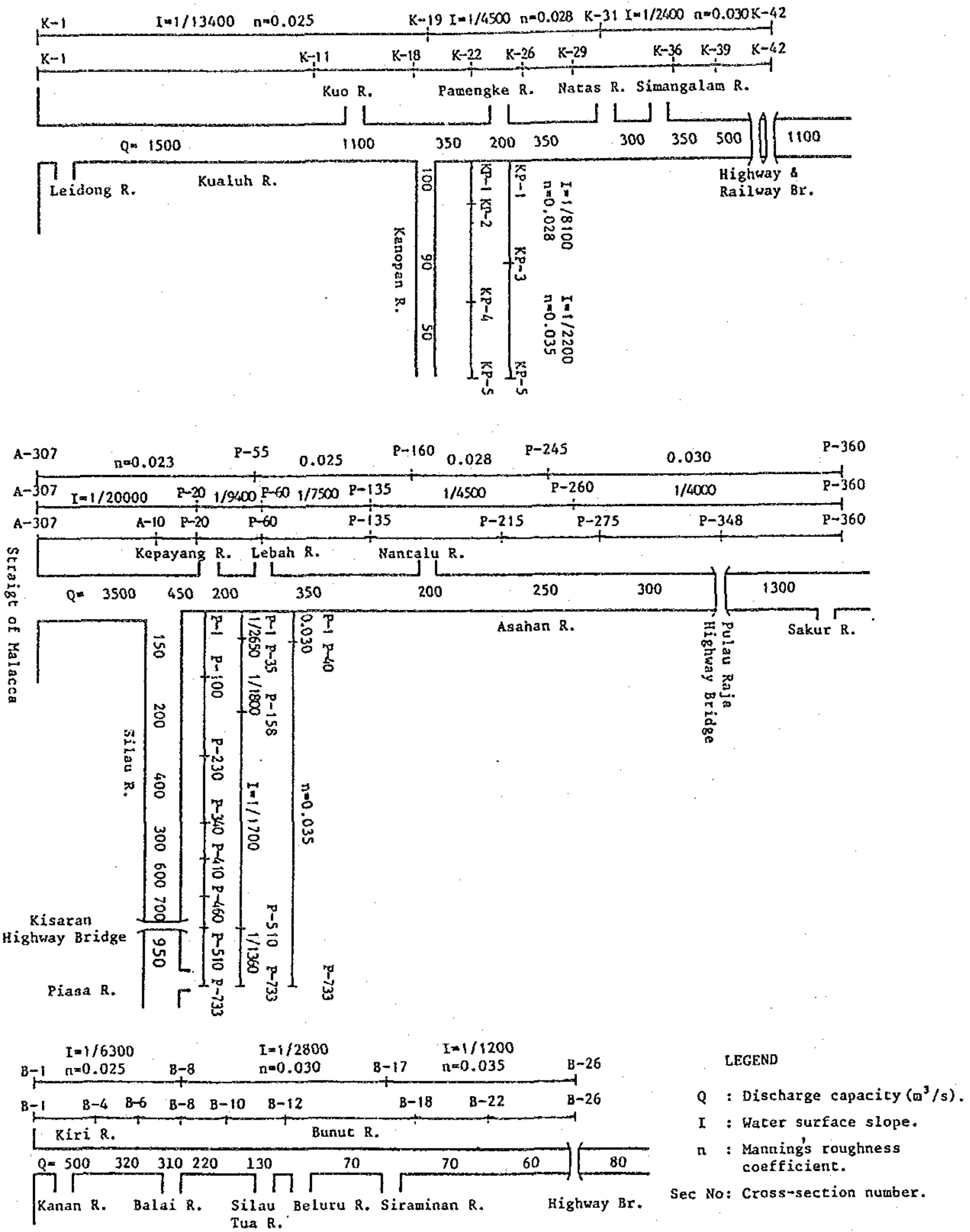


Fig.F-5 Location Map of Existing Dikes

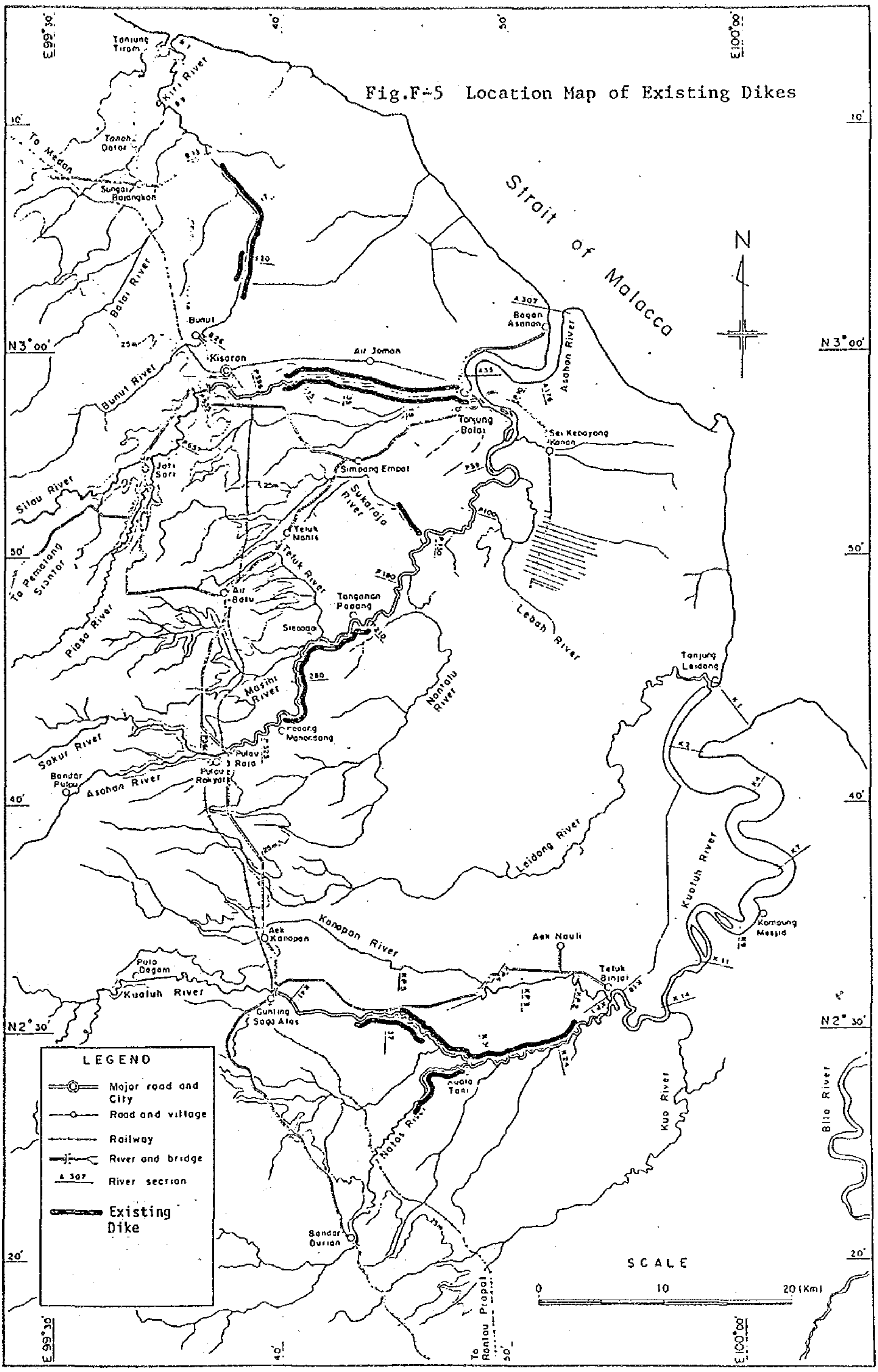
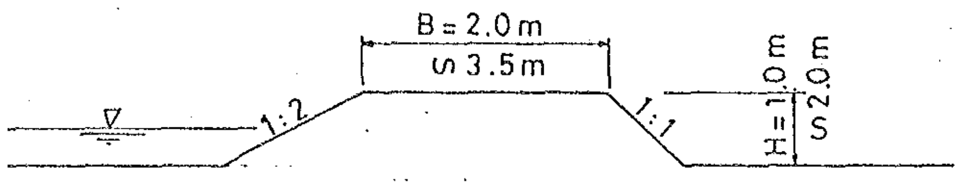
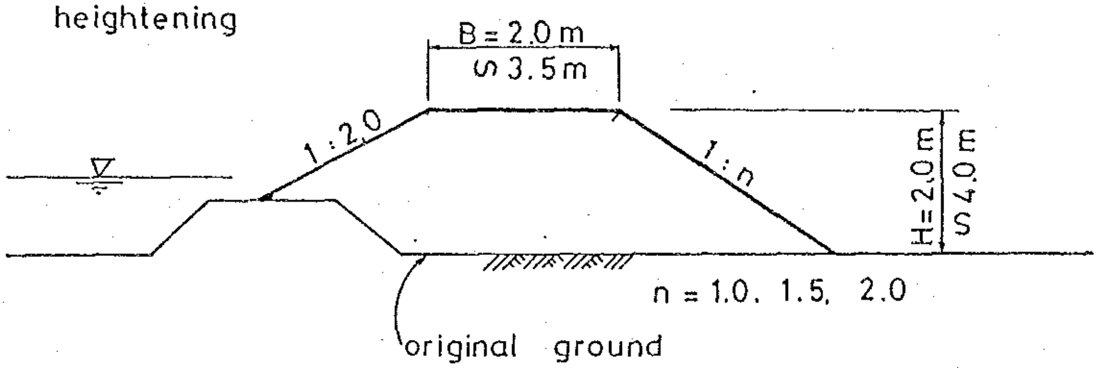


Fig. F-6 Typical Cross-Section of Existing Dike

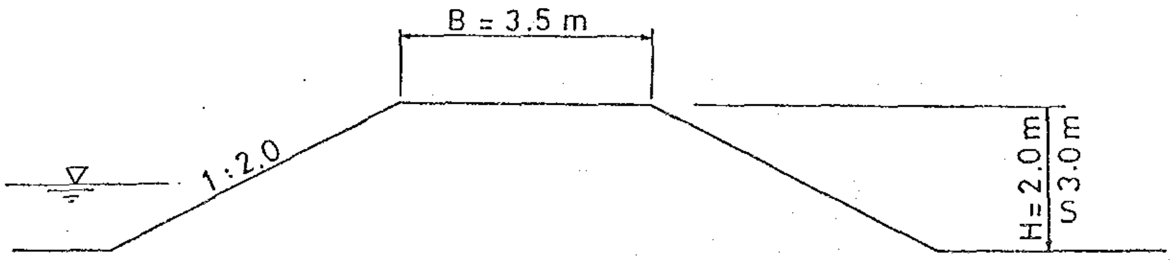
Asahan river



heightening



Silau river



heightening

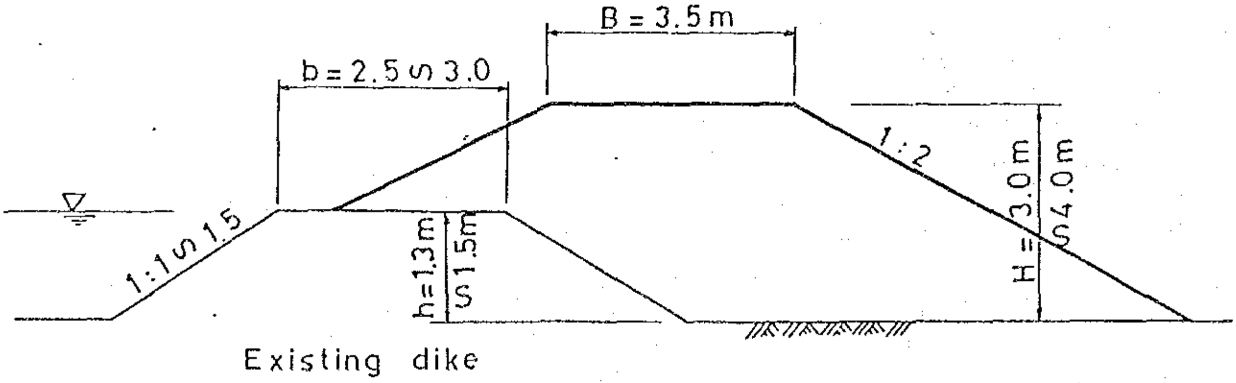
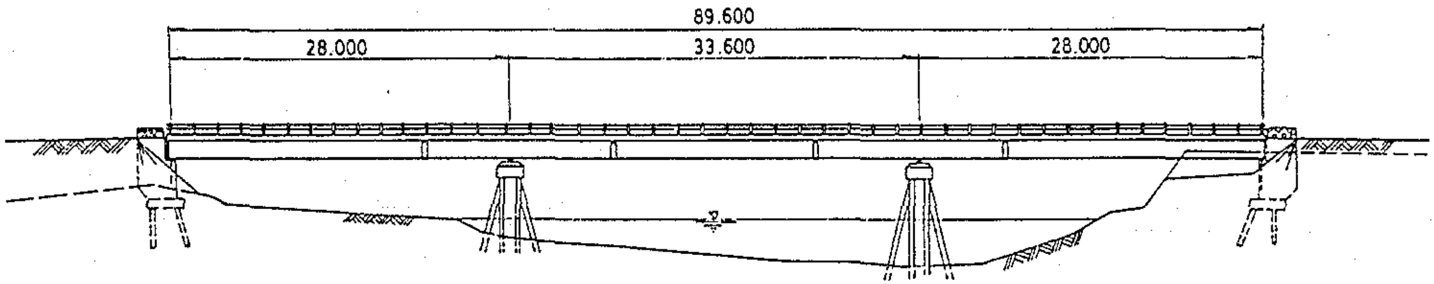
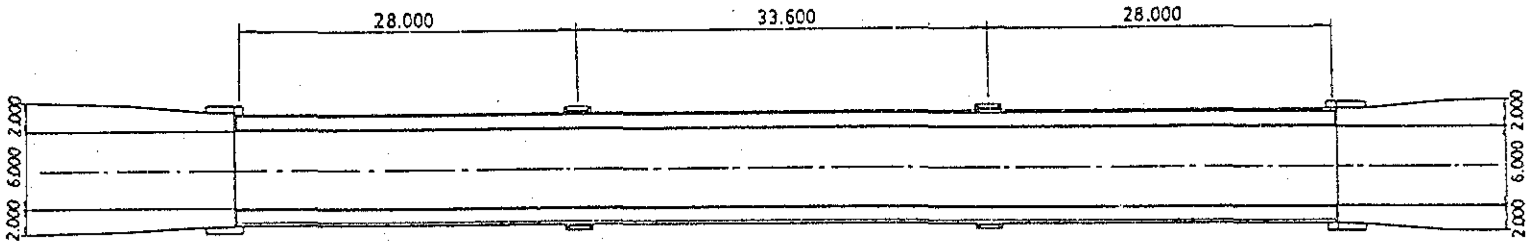


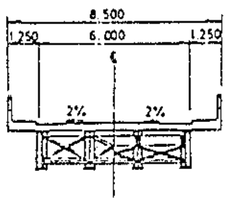
Fig.F-7 Profile of Highway Bridges (1/3) (at Pulau Raja, Asahan River)



Elevation



Plan



Section

Fig.F-7 Profile of Highway Bridges (2/3)
(at Tanjung Balai, Silau River)

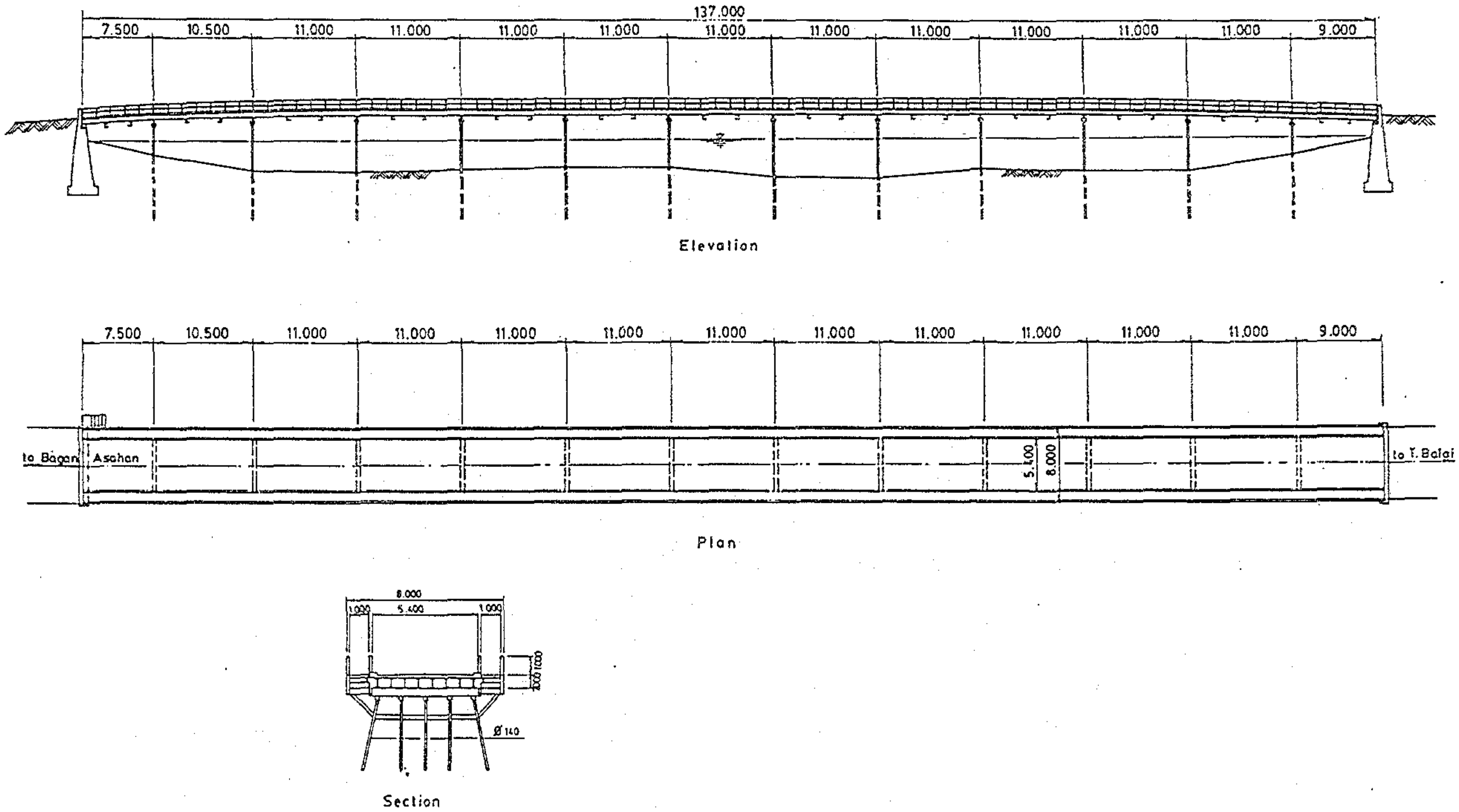
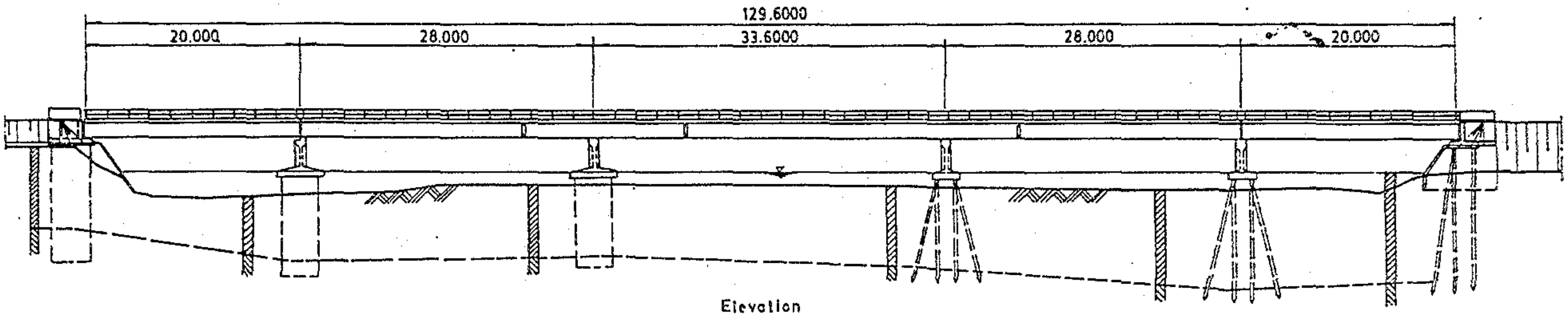
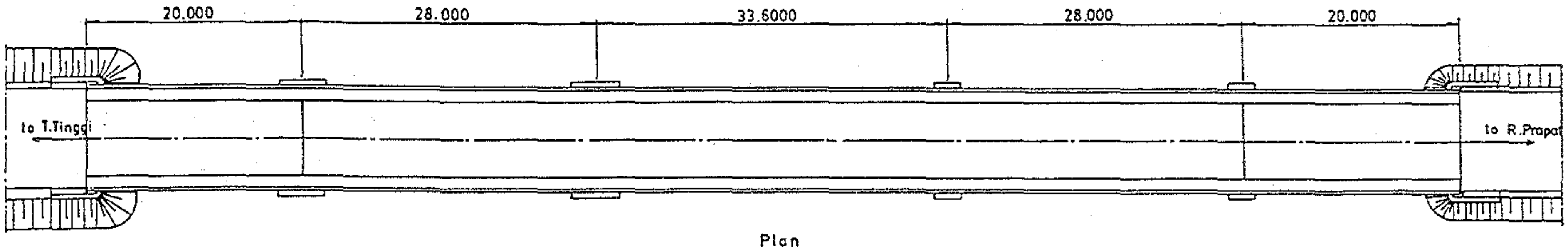


Fig.F-7 Profile of Highway Bridges (3/3)
(at Kisaran, Silau River)





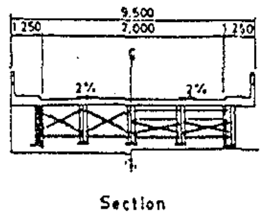


Fig. F-8 Profile of Intakes (1/6)
(Padang Mahondang Irrigation Intake, Silau R.)

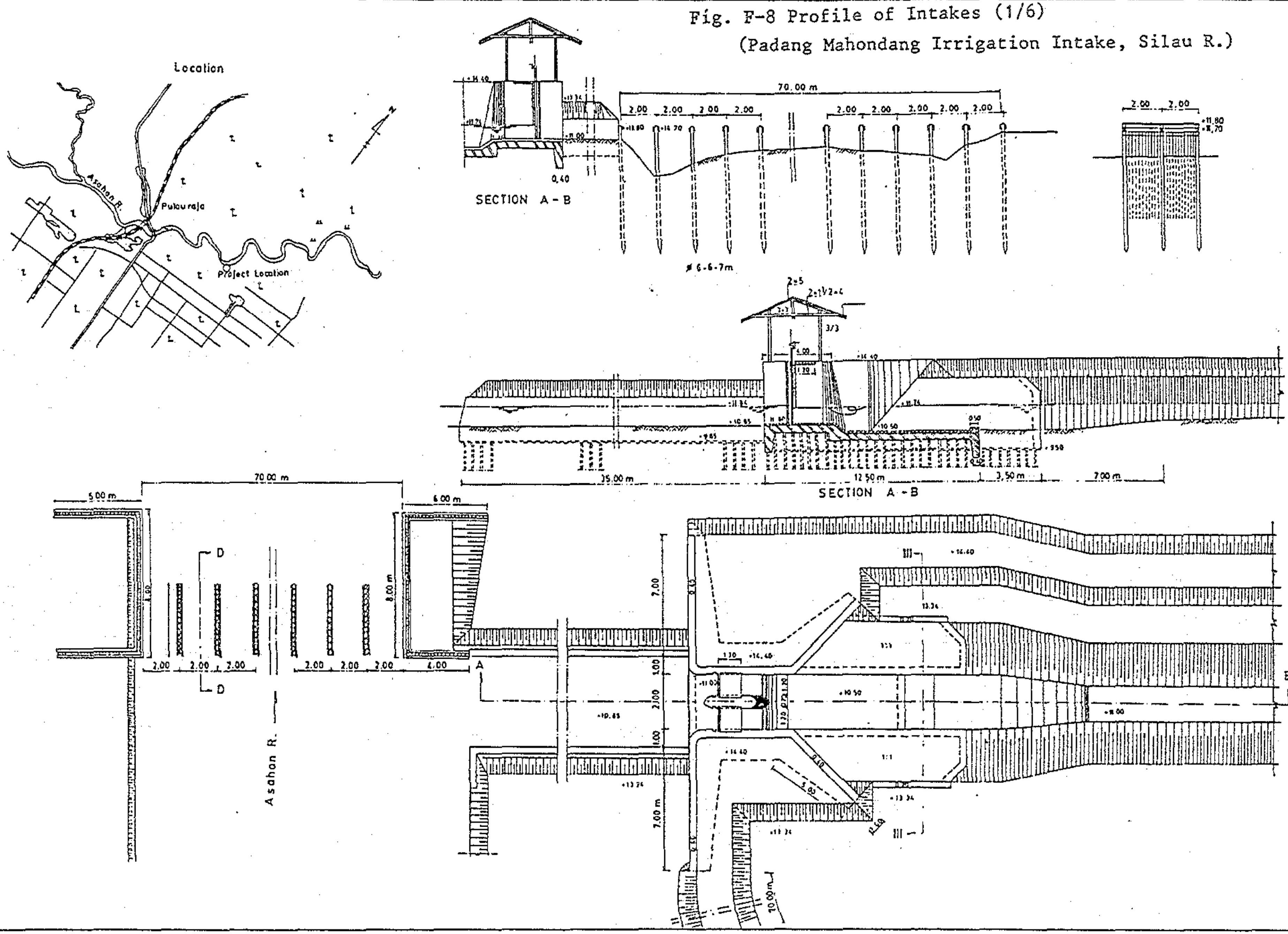
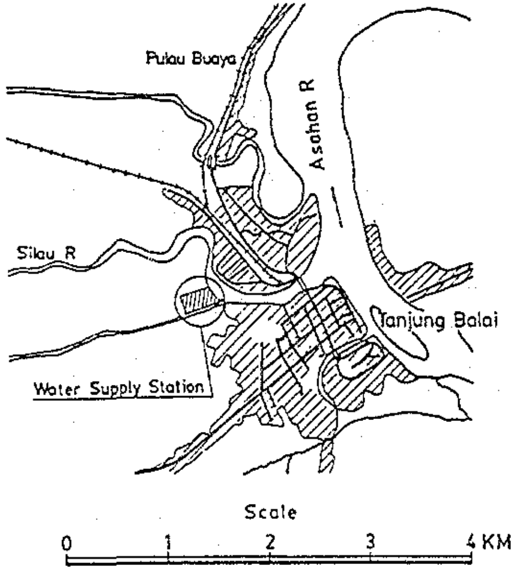
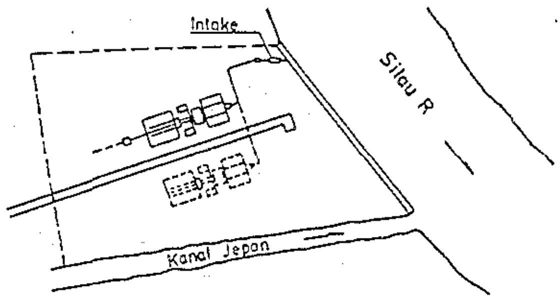


Fig. F-8 Profile of Intakes (2/6)
(Tanjung Bali Water Supply Intake, Silau R.)

Location

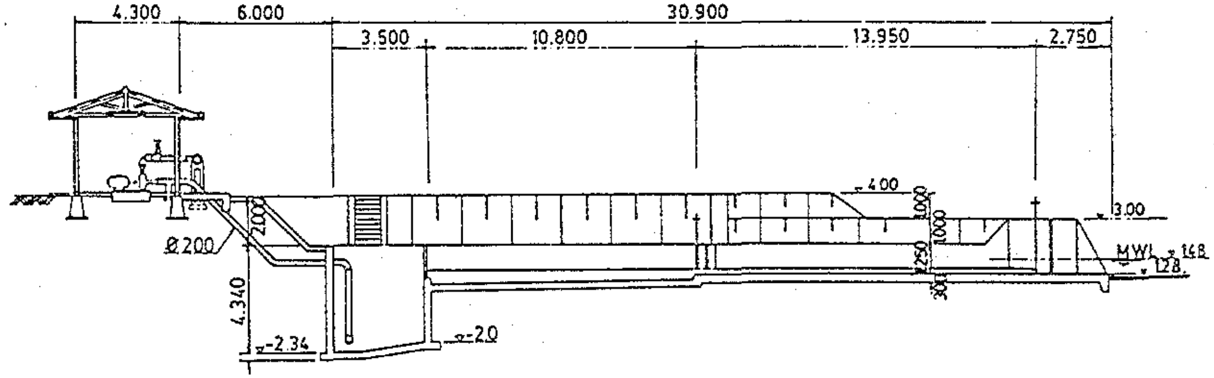


Sketch

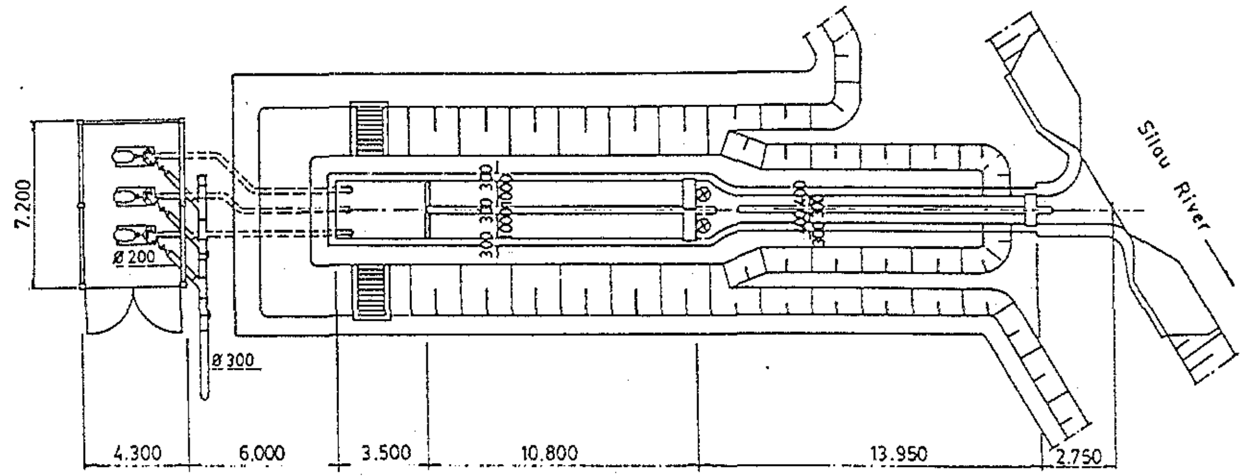


Extension

Intake Facility

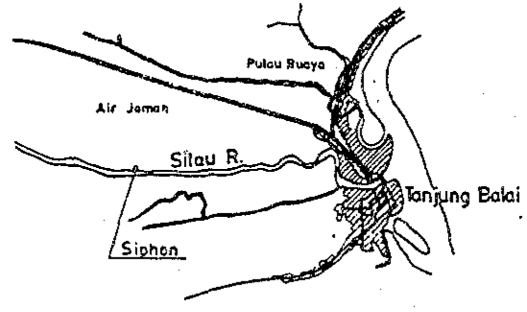


Elevation

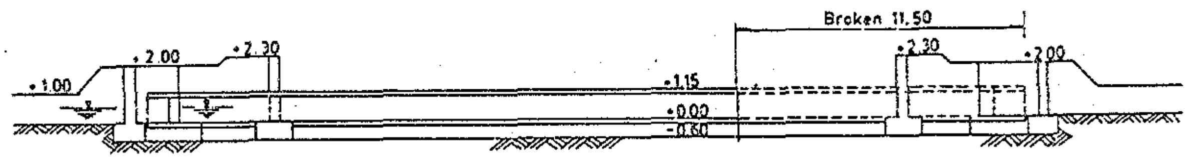


Plan

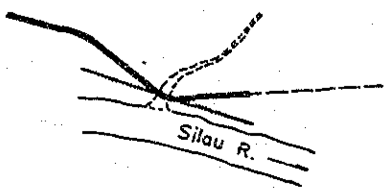
Fig. F-8 Profile of Intakes (3/6)
(Tasik Malaya Irrigation Intake, Silau R.)



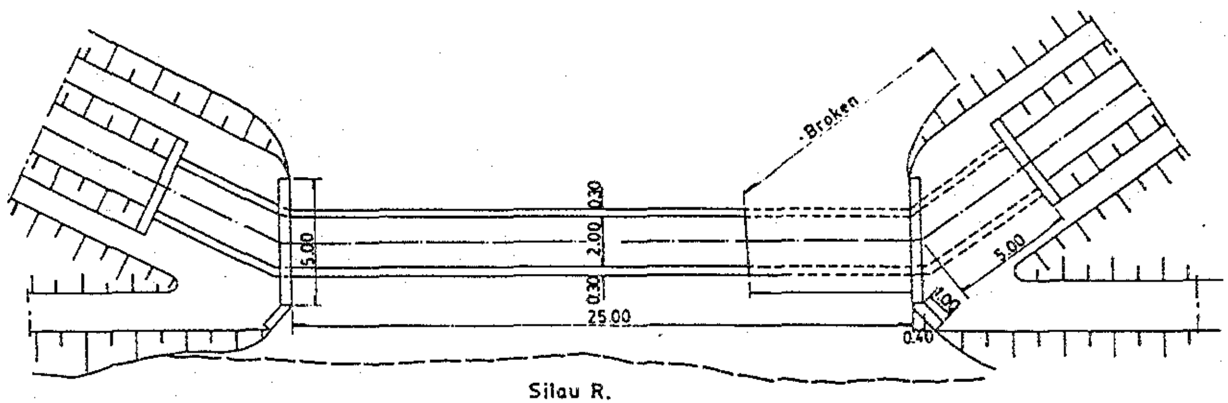
Location



Elevation



Sketch



Plan

Fig. F-8 Profile of Intakes (4/6)
(Srikamak II Irrigation Intake, Silau R.)

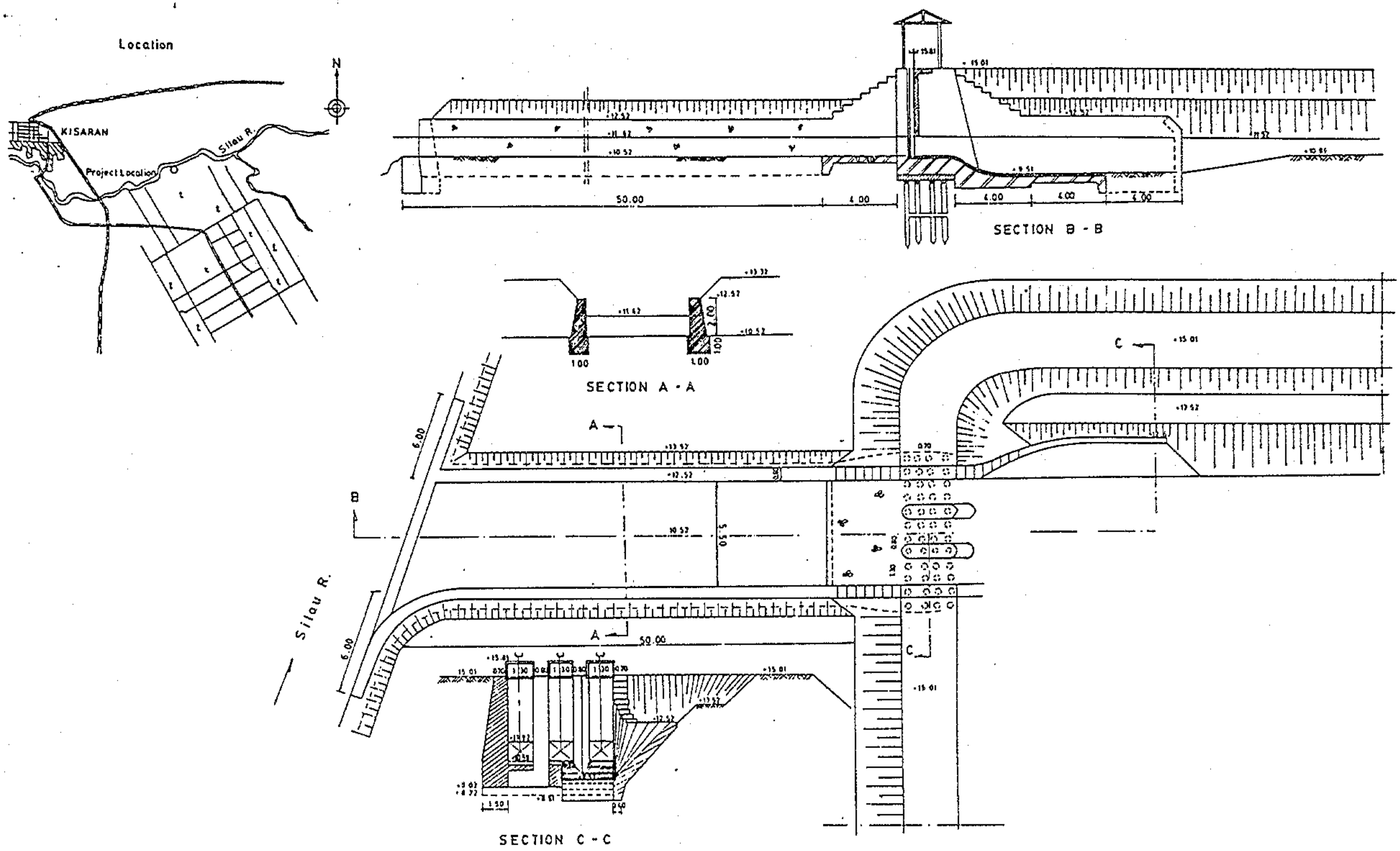


Fig. F-8 Profile of Intakes (5/6)

(Sinmbut-umbut Irrigation Intake, Silau R.)

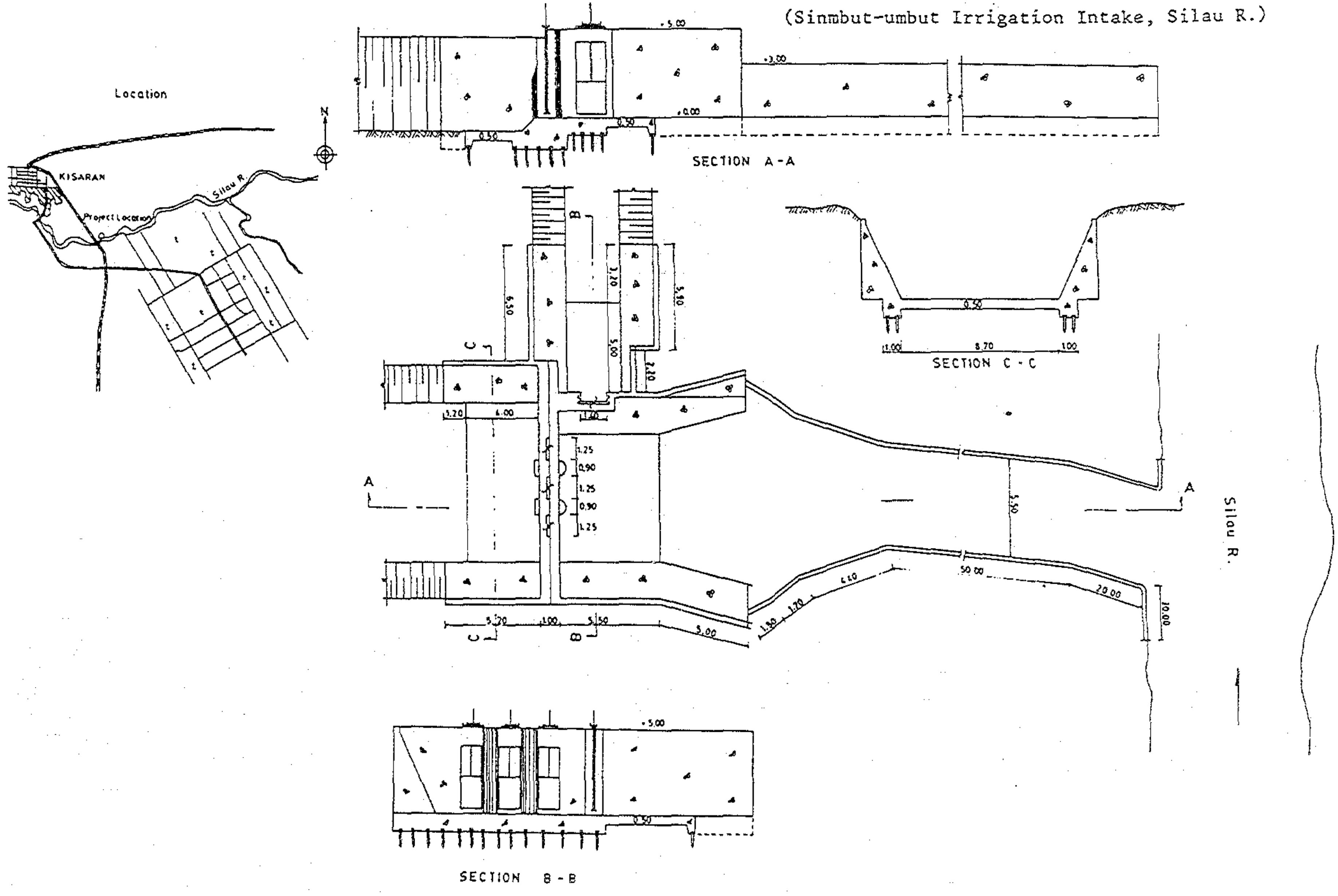
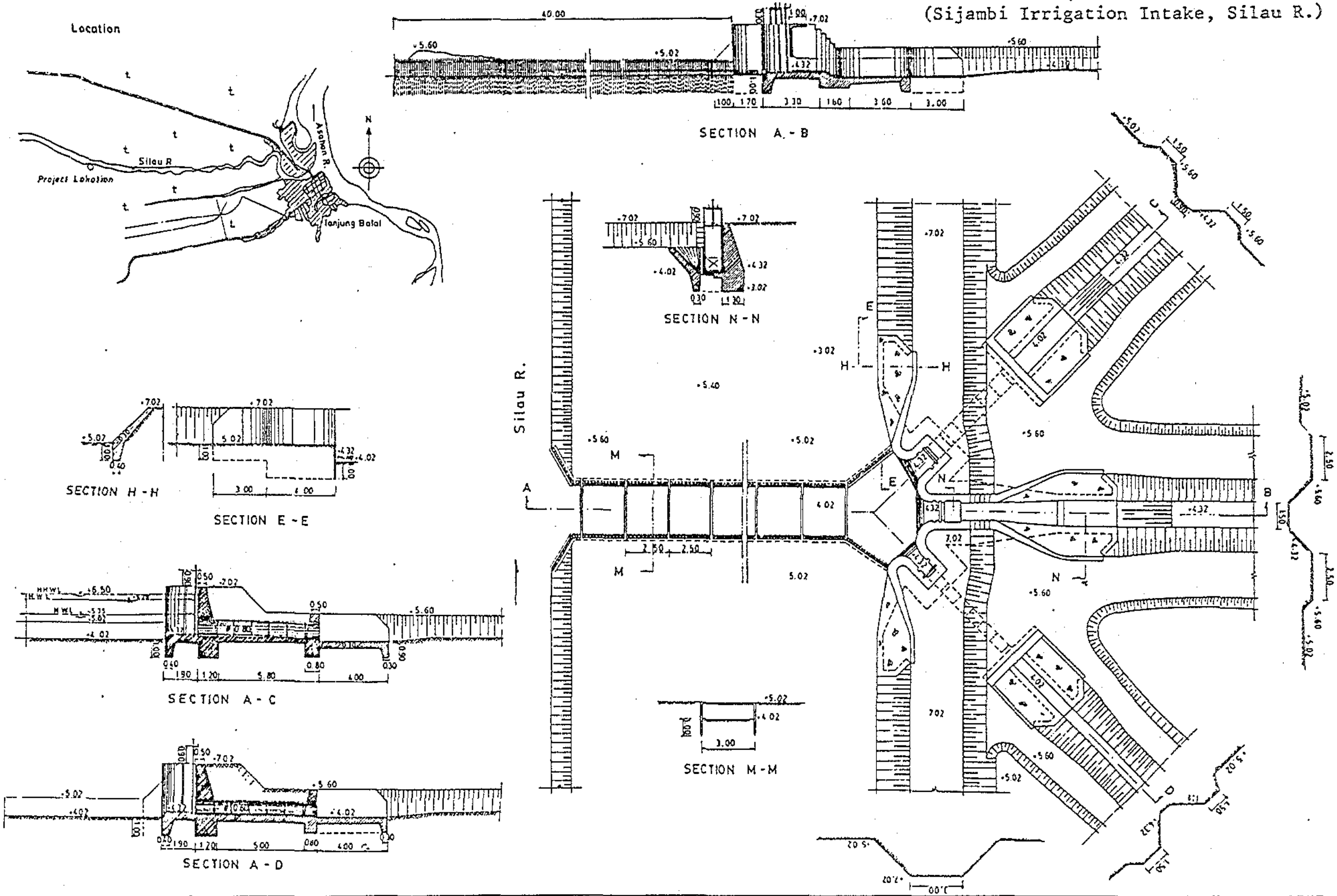


Fig. F-8 Profile of Intakes (6/6)

(Sijambi Irrigation Intake, Silau R.)



Appendix 2-G

Flood Discharge and Damages

Appendix 2-G

FLOOD DISCHARGE AND DAMAGES

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1. General

This Appendix 2-G presents detailed description with regard to flood discharge analysis and flood damage study including their methodology and basic approaches.

The runoff mechanism of major past floods is simulated with regard to the Asahan, Silau and Kualuh river basins. Probable flood discharge is estimated under the conditions of both existing and alternative flood control schemes on the basis of simulation analysis of the past floods. Detailed discussion for the alternative schemes is presented in Appendix 2-H.

Probable flood damages and average annual flood damages are estimated based on the flood-runoff analysis.

2. Flood Discharge

2.1 Past Major Floods

Water-level data were available at Pulau Raja, Kisaran and Pulo Dogom since 1977, 1973 and 1979 respectively, although it might be subjected to error in estimating flood-peak stages. Because some of them were obtained from thrice-daily staff-gage readings at 7 A.M., 12 A.M. and 5 P.M. while a series of heavy rainfall usually happens before midnight and flood due to them reaches the water-level gaging stations within 6 or 7 hours. The annual maximum discharges which were given by converting corresponding water levels are shown in Table G-1.

It is recognized that the flood of Jan. 1984 was the most remarkable for Pulau Raja and Pulo Dogom while Kisaran experienced the biggest one in December 1973. The basin seems to have encountered annual maximum floods as often in September through January and also in May. It should be noticed that the discharges at Pulau Raja have been affected by the regulation of the dams upstream since February 1981. The maximum flood peak from the residual drainage area upstream from Pulau Raja seems to be recorded in September 1977 when Kisaran also experienced the second biggest flood in peak discharge since 1973.

On the other hand, the Asahan and Silau river basins might be experienced most remarkable damage due to the same flood in December 1973 according to verbal information from the site. The maximum discharge of the flood seems to be 800 m^3/sec on the basis of discontinuous hydrography at Kisaran. In addition average basin rainfalls both of Pulau Raja and Kisaran in December 1, 1973 are situated in first and secondary ranks since 1963, that is, exceedance probabilities are 1/11 and 1/22 at least, respectively.

2.2 Flood Discharge Analysis of Asahan and Silau Rivers

2.2.1 Flood runoff from Asahan and Silau river basins

The Asahan and Silau river basins were divided into sub-basins as shown in Fig. G-1. The flood simulation model to analyze flood runoff mechanism of the Asahan and Silau river basins was installed by the Study Team. The model simulates hydraulic behavior in the basin as it responds to various flow conditions. It incorporates river basin components of sub-basins, channels, dams and retarding basins as shown in Fig. G-2. The storage-function method was selected among analytical tools to calculate flood runoff from each sub-basin and channel. Its general features are shown in Table G-2. The storage coefficients which compose the storage functions depend on both basin and channel conditions. Hydrological conditions during the floods of May 1975, Sept./Oct. 1977, May 1982 and Jan. 1984 were selected to determine the storage coefficients taking into account completeness of hydrological data, size of peak flood discharge and volume, duration of high water and amount of flood damage. The former two floods occurred before the construction of the Regulating and Tangga dams while the others occurred after the completion of the dams.

Average basin rainfalls to be hydrological input to the simulation model as well as falling pattern were estimated by use of isohyetal maps during the same periods because of poor records in mountainous area of which rainfall volume seems to be predominant in flood times.

Hydraulic response of the simulation model to rainfall input has to show almost the same discharge hydrographs which were observed at Pulau Raja and Kisaran if the storage coefficients are reasonable. The storage coefficients of sub-basin which were determined after several trials are shown in Table G-3. The discharge - storage relations of channels were also determined as shown in Table G-4 assuming channel conditions which is shown in Table G-5. Calculated hydrographs of flood discharge are shown in Fig. G-3 with actually observed records to demonstrate their coincidence.

(1) Runoff from residual area

After verification of the simulation model probable flood discharge was calculated with an assumption that hourly distribution of rainfall during the Sept./Oct. 1977 flood would be emerged. Because peak discharge from the residual drainage area of Pulau Raja which excludes runoff from Lake Toba is the biggest in the recorded period since 1977, and Kisaran experienced the second biggest peak in discharge since 1973. In addition accumulated rainfall of the 1977 flood on hourly basis shows highly concentrated pattern as compared with those of others as shown in Fig. G-4, which would provide the biggest discharge in peak. Although the Dec. 1973 flood should also be taken into consideration as a typical runoff pattern which might possibly be design flood, both data on hourly rainfall distribution and water level hydrograph at Pulau Raja are not recorded.

Probable one-day rainfall volume was taken up for the calculation of probable discharge because of the reasons below:

(a) All the rainfalls are daily measured at 7 A.M. every day,
(b) Concentration time is 6 or 7 hours,
(c) Most of rainfall series which bring floods start in the evening,
(d) Time interval between rainfall series is longer than the concentration time.

(2) Runoff from Lake Toba

Data on water level of Lake Toba is available during the period of 1916 through 1932, and also from 1957 to 1984. On the other hand, outflow of Lake Toba has been observed at Siruar/Regulating dam since 1956. Annual maximum water level and outflow of Lake Toba by present regulation rule were calculated using 10-day average net inflow estimated from the above data with an assumption that initial water level of Lake Toba is El. 905.0 m at the beginning of flood. On the basis of the calculation result probable maximum outflow which was regulated by the Regulating dam was estimated as follows:

Return period (year)	:	2	5	10	15	20	25	30	50	100
Max. outflow (m^3/sec)	:	315	400	400	400	400	400	400	400	400

Detail description is presented at Appendix 2-K.

(3) Flood overlapping study

Major floods in the past of which daily discharge was bigger than 170 m^3/sec for the residual area of Pulau Raja and also 200 m^3/sec for Kisaran were picked up by the Study Team in consideration of discharge capacity of existing channel. Seasonal distribution of the flood frequency is shown in Fig. 5. The following flood characteristics were recognized from the frequency analysis:

(a) Flood is often appeared during September through January and also in May,

(b) From a viewpoint of flood size, bigger floods occur in September through January.

Objective flood of Sep./Oct. 1977 is recognized as a typical flood which satisfies the above characteristics. Considering that major floods have often been observed from September to January, big flood might possibly occur in December when the Regulating dam spills the annual maximum discharge.

On the other hand, from a viewpoint of rainfall records since 1963 when most of rainfall gaging stations started their operations, it is recognized that the residual area received much rainfall during three months from October to December in 1963 and 1969 as shown in Fig. G-6. In the same period the Regulating dam spilled remarkable outflow.

In conclusion, it is assumed that the basin receives the probable outflow from the Regulating dam in addition to the probable flood discharge from the residual area at the same time.

(4) Probable flood discharge

On the basis of the above conclusion, probable peak flood discharge was calculated at major points under present conditions. They are shown in Table G-6. Probable peak discharges under the conditions of proposed flood control schemes is also shown in Table G-7. They were calculated by use of discharge - storage relations of improved channels as shown in Table G-8, which were given with an assumption of channel conditions in Table G-9. The runoff simulation model of the alternative schemes are shown in Fig. G-7. Detailed description with regard to the alternative schemes is presented in Appendix 2-H.

2.2.2 Flooding in Lower Area

In addition to the runoff simulation mentioned above, flooding condition in lower areas of the Asahan and Silau rivers was also analyzed. The lower area which has suffered from habitual inundation is recognized in the right bank of the Asahan downstream from Pulau Raja and the both sides of the Silau downstream of Kisaran. In the analysis flooding mechanism was classified into two types, that is, storage type and diffusion type in consideration of topographic features.

The diffusion-type flooding is appeared in the upper part of the area, and its topographic feature shows gentle slopes. The excess water over the river bank flows downward on the flood-plain without standing, while flow width varies depending on the discharge. On the basis of information on damage due to the past floods of Sept./Oct. 1977, May 1982 and Jan. 1984, the flooding conditions were estimated assuming Manning's n and slope as 0.08 and 1/2,000 respectively. They are shown in Table G-10.

On the other hand, the storage-type flooding is appeared in the downstream part of the area. Its topographic feature is almost flat, and store the overflow water over the river bank because of the shortage of drainage capacity. Maximum water level, inundation area and stored volume were estimated by use of the following equation:

$$dS(t)/dt = I(t) - O(t) \qquad \text{Eq(G.1)}$$

where,
- $S(t)$: storage (m^3)
- $I(t)$: inflow (m^3/sec)
- $O(t)$: outflow (m^3/sec)
- t : time (sec)

The estimated maximum flooding condition during the flood time is shown in Table G-10.

Flooding condition due to probable floods was also estimated as shown in Table G-11. In the calculation of the diffusion-type flooding, it is assumed that overflow water spreads down with constant depths of 0.6 m and 0.5 m for the Asahan and Silau rivers respectively in consideration of the past flooding condition. Because the overbank flow spreads so widely without much difference in depths even though inflow discharge is increased. The maximum flooding condition in the storage-type flooding area was also estimated by use of hydrographs of probable floods as shown in Table G-11.

2.3 Flood Discharge Analysis of Kualuh and Kiri River Basins

The same methodology as those of the Asahan and Silau river basins was used to analyze flood runoff from the Kualuh and Kiri river basins. Flood-runoff simulation model was provided by the Study Team as shown in Fig. G-8, of which sub-basins are shown in foregoing Fig. G-1.

The simulation model of the Kualuh river basin was examined to determine storage coefficients of sub-basins under the hydrological conditions in major past floods of Sep. 1983 and Jan. 1984. Simulated discharge hydrographs during the flood times are shown in Fig. G-9 with observed data. Estimated storage coefficients are also shown in Table G-12. As for runoff calculation of channels discharge - storage relations were provided as shown in Table G-13 assuming channel conditions shown in Table G-14.

The storage coefficients of the Kiri river basin were estimated in consideration of those of the Asahan and Silau river basins because discharge hydrograph of any flood has not been recorded. They are shown in Table G-15. Discharge - storage relations and assumed channel conditions are also shown in Tables G-16 and G-14 respectively.

Probable flood discharge of the both river basins was calculated at major points under present conditions. They are shown in Table G-17. Probable flood discharge under the conditions of the alternative flood control plans, which is explained in APPENDIX H, is also shown in Table G-18. It is assumed that discharge - storage relations are changed by improved channel conditions. They are shown in Tables G-19 to G-21.

3. Flooding Mechanism

3.1 Flooding Characteristics

The river basins are situated in heavy rainfall zone by the monsoons and characterized by the topographic features of river profiles with steep slope. Such heavy rainfall frequently brings about inundation in low-lying area of the lower basin.

After heavy rainfall in the mountainous areas, the river stage rises rapidly in the middle reaches and river water overtops the bank exceeding the discharge capacity. The flooding in the plain thus may be caused by the following two factors:

(a) Overbank flow of flood water due to small discharge capacity of channel.

(b) Insufficient capacity of drainage system in low-lying area.

Figure G-10 shows possible flooding areas based on the data collected from DPUP, North Sumatra and the informations obtained through field survey.

The flooding conditions for each river are as follows:

(1) Bunut river

As the drainage area of the Bunut river is small of 120 km^2 at Serbangan irrigation weir, flood discharge and inundated area were comparatively small even in the September 1983 flood. After construction of dikes of 14 km in total length, flood damage has been further reduced.

(2) Silau river

The Silau river has continuous dikes on the both banks in the stretch between Kisaran and near Tanjung Balai. But those dikes have often been destroyed, especially in the downstream reaches, even by discharges less than its discharge capacity. It seems that those dikes are as a whole not firm and maintained with insufficiency.

(3) Asahan river

The Asahan river also has dike of 11 km long on the right bank in the downstream reaches of Pulau Raja. This dike has occasionally been destroyed by floods due to the same reasons as those of the Silau river.

The overtopping excess water runs eastward and the area on the right bank is inundated. The duration of inundation is considerably long as two or three months.

In the downstream reaches from the existing dike, the discharge capacity is smaller than that of the upstream reaches so that the excess water above capacity intrudes into the broad swamp on the right bank through various small tributaries, and the whole swamp area becomes a huge flood-plain.

In the swamp area, an intricate channel network and several rivers exist, but this system is completely inadequate to evacuate the water. As a consequence, this area is inundated for considerable long time.

(4) Kualuh river

The most floods overflow mainly to the left bank area in the middle reaches downstream from highway bridge due to the topography. The area which consists of considerably large paddy field had often suffered from floodings before the present dikes were constructed in total length of 29 km. Since then floodings have been reduced remarkably.

3.2 Flooding Conditions

According to the data on the past floods collected from DPUP, North Sumatra and the informations obtained through the field survey, the floods in the last eight years from 1977 to 1984 are as follows:

Bunut river	:	Sep. 1983
Silau river	:	Sep. 1977, Apr. 1983, May 1983, Feb. 1984, Apr. 1984, May 1984 and Sep. 1984.
Asahan river	:	Oct. 1977, Dec. 1978, Mar. 1980, Apr. 1982, May 1982 and Jan. 1984.
Kualuh river	:	Sep. 1983, Oct. 1983 and Jan. 1984.

Out of them, the following floods are selected for the estimation of flooding conditions and damage.

Asahan river	:	Sep. 1977, May 1982 and Jan. 1984
Silau river	:	Sep. 1977, May 1982 and May 1984

In order to estimate flooding conditions, a contour map of the study area is made as shown in Fig. g-11 based on the existing data on topography. Both the contour map and results of discharge analysis in the lower area, provided flooding conditions such as inundated area, depth and duration of the said floods as shown in Table G-22.

The flooding conditions for probable floods of 2-, 10-, 30- and 100-year were also estimated as shown in Table G-23. The probable inundation area of the 10-yr and 30-yr floods are presented in Fig. G-12.

4. Flood Damages

4.1 Methodology

4.1.1 Basic strategy

Flood damages are estimated in principle, from properties in flooding area multiplied by the damage rate depending on the flooding conditions. The damages are estimated for respective properties such as house/building, household effects, stored goods, agricultural crops, public facilities and others. Damages consist of direct and indirect damages. Direct damages are further classified into three categories such as damages to buildings including properties therein, agricultural products and public facilities.

Flood damages under future condition in the year of AD 2005 are also estimated for the establishment of the long-term plan in the study area.

All the monetary values are expressed by the economic prices as of the end of March 1985. The conversion rate of foreign and local currencies are assumed at:

US$1 = Rp. 1,100 = Japanese ¥250

The methods adopted to the estimation of damages for respective properties are discussed further in the following paragraphs.

4.1.2 Damages to house and household effects

(1) Damages to houses

The unit value of residence/farmhouse under present conditions is estimated as:

$$Vh = Af \times Cev \quad \text{------------------------------} \quad Eq(G.2)$$
$$= 75\ m^2 \times Rp.\ 22{,}400/m^2 = Rp.1{,}680{,}000/\text{house in urban area}$$

$= 45\ m^2 \times Rp.\ 13,400/m^2 = Rp.\ 605,000$/house in rural area

where,	Vh	:	unit value of a house (Rp./house),
	Af	:	average floor space for a house (m^2), and
	Cev	:	evaluated price for unit area (Rp./m^2).

A weighted-mean floor space of residence/farmhouse are estimated as shown in Table G-24. As for the price of unit area for a house, weighted-mean price of temporary, small, semi-permanent and permanent houses is applied as shown in Table G-25.

Damages to residence/farmhouses in AD 2005 are estimated based on the increases of unit value and population. Unit value of residence in urban area, e.g. in Tanjung Balai, is assumed to increase to Rp. 1,875,000 for a house though the number of houses does not change.

Unit value of residence/farmhouse in rural area is estimated using the average growth rate of population and increase of unit value. Growth rate of 1.2% per annum (1980 to 1983 in Kabs. Asahan and Labuhan Batu) is applied for the estimation under future condition. Evaluated price for unit area of house is assumed to increase to Rp. 17,600/m^2.

(2) Damages to household effects

The values of total household effects in residence or farmhouse are estimated as follows:

$$Vhe = Qhe \times P \quad \text{--------------------------------} \quad Eq(G.3)$$

$= Rp.\ 857,800$/house $\times\ 2.29 = Rp.1,960,000$/house in urban area

$= Rp.\ 528,900$/house $\times\ 2.29 = Rp.1,210,000$/house in rural area

where,	Vhe	:	value of household effects per house (Rp./house),
	Qhe	:	standard value of household effects for each house (Rp./house), and
	P	:	index for estimation of current value in 1985. (= 2.29 = 1.30 x 1.76)

The standard value of house household effects are estimated using the data on monthly family expenditure in 1980 as shown in Table G-26. The average period of use and duration life of property are considered for the estimation.

Growth rate of per-capita regional income and consumer price index (CPI) of North Sumatra, which are provided in Table G-27, are applied for the estimation of the index P.

Future increase of household effects is estimated based on the increase of GRDP in commercial sector. The annual growth rate of 4.5% is adopted considering the circumstances of surrounding area.

(3) Damage rate

The rates of damage to house/building and household effects are presented in Table G-28 applying Japanese standards which are also adopted in the similar projects in Indonesia.

4.1.3 Damages to commercial sector

(1) Damages to building

The unit value of buildings in commercial sector such as store, trade, restaurant and hotel is estimated as follows:

$$
\begin{aligned}
Vs &= Af \times Cev \quad \text{-------------------------------------} \quad Eq(G.4) \\
&= 150\ m^2 \times Rp.\ 25{,}000/m^2 = Rp.3{,}750{,}000/\text{building in urban area} \\
&= 100\ m^2 \times Rp.\ 15{,}000/m^2 = Rp.1{,}500{,}000/\text{building in rural area}
\end{aligned}
$$

where,
- Vs : unit value of building in commercial sector (Rp./building),
- Af : average floor space for a building (m^2), and
- Cev : evaluated price for unit area (Rp./m^2).

The existing buildings of commercial sector are assumed to be permanent and semi-permanent houses for urban and rural areas respectively.

Damages to buildings in AD 2005 are estimated based on the increases of unit value and number of buildings. Unit value of building in urban area is assumed to increase to Rp. 4,500,000/building though the number of building is not change.

Unit value of building in rural area is estimated using the average increase of GRDP in commercial sector. The annual growth rate of 4.5% is adopted for the estimation.

(2) Damages to household effects in commercial sector

Numbers of house/building and household in each Kecamatan and Kodya Tanjung Balai in and around the flood prone area are presented as shown Tables G-29 and G-30. Total number of houses/buildings except "others", which is one of the items for number of house/building, corresponds to the number of households, because owners and their families in Indonesia generally live in their stores, restaurants, hotels and small industries. Considering the above matters, the value of household effects in commercial sector are estimated in similar manner as that in residence/farmhouse, e.g.,

$$Vhe = Qhe \times P \quad \text{-----------------------------} \quad Eq(G.5)$$
$$= \text{Rp. } 857{,}800/\text{building} \times 2.29 = \text{Rp.}1{,}960{,}000/\text{building in urban area}$$
$$= \text{Rp. } 528{,}900/\text{building} \times 2.29 = \text{Rp.}1{,}210{,}000/\text{building in rural area}$$

Increase of household effects in AD 2005 is estimated based on the increase of GRDP in commercial sector. The annual growth rate of 4.5% is adopted for the estimation.

(3) Damages to stored goods

The value of stored goods in commercial sector is estimated as follows:

$$Vc = (Vsf + Vsd + Vsc + Vsfl + Vsp) \times P \quad \text{-----------------} \quad Eq(G.6)$$
$$= \text{Rp. } 1{,}234{,}000/\text{building} \times 1.76 = \text{Rp. } 2{,}170{,}000/\text{building}$$

where,
- Vc : value of stored goods in commercial sector,
- Vsf : stock value of food and beverage,
- Vsd : stock value of furnishing/durable goods,
- Vsfl : stock value of fuel, light, water for house,
- Vsp : stock value of personal goods, and
- P : index for estimation of current value in 1985 (= 1.76).

The total stock value is estimated as shown in Table G-31 with their 1980-prices. The quantity of stored goods in a store in 1985 is assumed to be same as those in 1980, and the average increase of CPI is applied for the index P. The value of Rp. 2,170,000/building is also applied for that of the Kualuh river area in Kab. Labuhan Batu.

Increase of stored goods in commercial sector in AD 2005 is estimated based on the increase of GRDP in commercial sector. The annual growth rate of 4.5% is adopted for the estimation.

(4) Damage rate

The rates of damage to buildings, household effects and stored goods in commercial sector are shown in Table G-28 applying the standard in Japan.

4.1.4 Damages to small industry

(1) Damages to buildings

The unit value of small industry is estimated as follows:

$$Vi = Af \times Cev \quad \text{--} \quad Eq(G.7)$$
$$= 200\ m^2 \times Rp.\ 25{,}000/m^2 = Rp.\ 5{,}000{,}000/\text{workshop in urban area}$$
$$= 200\ m^2 \times Rp.\ 20{,}000/m^2 = Rp.\ 4{,}000{,}000/\text{workshop in rural area}$$

where, Vi : unit value of small industry (Rp./workshop),
Af : average floor space for a workshop (m^2), and
Cev : evaluated price for unit area (Rp./m^2)

Damages to workshop in AD 2005 are estimated based on the increases of unit value and number of workshops. Unit value of workshop in urban area is assumed to increase to Rp. 6,000,000/workshop though the number of workshops is not change.

For the workshops in rural area, damages are estimated using the average increases of workshops and unit value. Average increase of 4% per annum in Kab. Asahan from 1980 to 1983 is adopted and unit value of workshop is assumed to increase to Rp. 4,800,000/
workshop.

(2) Damages to household effects in small industry

In the flood prone area of the Asahan and Silau rivers, workshops of handicraft, brick and clothes occupy about 85% of total workshops. As same as the commercial sector, owners and their families are assumed to live in their workshops. The values of total household effects in small industry are estimated in the same manner as that of ordinary house, e.g.,

$$
\begin{aligned}
Vhe &= Qhe \times P \quad \text{------------------------------} \quad Eq(G.8) \\
&= \text{Rp. } 857{,}000/\text{workshop} \times 2.29 = \text{Rp. } 1{,}960{,}000/\text{workshop in urban area} \\
&= \text{Rp. } 528{,}900/\text{workshop} \times 2.29 = \text{Rp. } 1{,}210{,}000/\text{workshop in rural area}
\end{aligned}
$$

Future increase of household effects is estimated based on the increase of GRDP in commercial sector. The annual growth rate of 4.5% is adopted for the estimation.

(3) Damages to property in small industry

The value of stored goods in a small industry is estimated as follows:

$$
\begin{aligned}
Vi &= Vsp + Vsm + Veq \quad \text{------------------------------} \quad Eq(G.9) \\
&= \text{Rp. } 10{,}340{,}000/\text{workshop}
\end{aligned}
$$

where,
- Vi : value of property in a small industry,
- Vsp : stock value of products,
- Vsm : stock value of raw materials, and
- Veq : value of machines and equipments.

The stock value of products and raw materials are estimated to be equivalent to half of monthly gross output and 82% of monthly input cost, respectively. The gross output and input cost per workshop are estimated by the GRDP in industry sector in Kab. Asahan.

The value of machines and equipments is estimated to be equivalent to ten times of annual capital cost which is calculated by the following equation:

$$
Cc = Pi/N - Clb \quad \text{------------------------------} \quad Eq(G.10)
$$

where,
- Cc : annual capital cost (Rp./workshop),
- Pi : GRDP in industry sector in Kab. Asahan (Rp./yr),
- N : number of establishment in Kab. Asahan, and
- Clb : total labor cost for one workshop.

Detail process of the estimation is presented in Table G-31.

Increase of stored goods in workshop in AD 2005 is estimated based on the increase of GRDP in industry sector. The annual growth rate of 7% is adopted for the estimation considering the circumstances of surrounding area.

(4) Damage rate

The rates of damages to buildings, household effects and property of workshop for small industry are shown in Table G-28 applying the standards in Japan.

4.1.5 Damages to other building

The unit value of other buildings such as local government office, mosque, church, school, etc., are estimated as follows:

$$
\begin{aligned}
Vo &= Af \times Cev \quad \text{--} \quad Eq(G.11) \\
&= 250\ m^2 \times Rp.\ 25{,}000/m^2 = Rp.\ 6{,}250{,}000/\text{building in urban area} \\
&= 200\ m^2 \times Rp.\ 25{,}000/m^2 = Rp.\ 5{,}000{,}000/\text{building in rural area}
\end{aligned}
$$

Damages in AD 2005 are assumed to be Rp. 7,500,000/building and Rp. 6,000,000/building for urban and rural areas respectively, based on the increase of unit value. In the rural area, increase of population (1.2% per annum) is also considered.

Damages to property in this category are assumed to be equivalent to 10% of the value of building.

Unit values of house/building, household effects and stored goods are summarized in Table G-33.

4.1.6 Damages to agricultural crops

(1) Wetland paddy

The unit value of wetland paddy are estimated as follows:

$$V_p = Y_p \times P_p \quad \text{--------------------------------} \quad Eq(G.12)$$

= 2.5 ton/ha x Rp. 193,000/ton = Rp. 482,500/ha
for the Asahan and Kualuh river areas in 1985

= 3.0 ton/ha x Rp. 193,000/ton = Rp. 564,000/ha
for the Silau and Bunut river areas in 1985

where, Vp : value of paddy field in net area (Rp./ha),
Yp : Unit yield rate of paddy (ton/ha), and
Pp : unit price of paddy (Rp./ton).

a. Unit price of paddy

Based on the price of rice predicted by the World Bank (IBRD), the firm-gate price of paddy (dry stalk paddy) is estimated at Rp. 193/kg and Rp. 251/kg in 1985 and 2005 respectively as shown in Table G-34. The unit yield rates of 2.5 ton/ha is adopted for the Asahan and Kualuh rivers. For the Silau and Bunut rivers, 3.0 ton/ha is adopted.

b. Cropping pattern and flood season

The representative cropping pattern in the study area is as follows:

Stage :	Transplanting	Tillering	Booling	Heading	Ripening
Month :	Oct.	Nov.	Dec.	Jan.	Feb.

On the other side, the area has a flood season from September to January which meets growing period of paddy.

c. Reduction rate

In consideration of growing stage of paddy in flood season, the yield reduction rates for respective flooding condition are presented in Table G-35.

(2) Upland crops

The upland crops are further classified into upland paddy, maize and soybean. These are the major crops in the Study Area.

For the damage estimation of upland paddy, the unit yield rate is assumed at 2.0 ton/ha and the unit price in Table G-34 is applied. The unit prices of maize and soybean are estimated as shown in Tables G-36 and G-37 respectively, and prices per unit area are listed in Table G-38 with paddy price. Their reduction rates are presented in Table G-35.

(3) Rubber, oil palm and other crops

Flood damages to other products such as cassava, sweet potato, peanut, and estate products of rubber and oil palm are assumed at 5% of the sum of the wetland paddy and upland crops.

4.1.7 Damages to public facilities

Damages to public facilities such as river dike, road, bridge, irrigation intake, canal and drainage outlet are assumed at 30% of the direct damages.

4.1.8 Indirect damages

The indirect damages which are accrued from the losses due to interruption of smooth traffic and other economic activities in the flooding area were assumed at 10% of the total direct flood damages.

4.2 Probable Flood Damage

4.2.1 Damages under present condition

Table G-39 shows the calculation result of probable flood damages under present conditions. Total flood damages are summarized below.

(Unit: Rp. million)

River	2-yr	5-yr	10-yr	15-yr	30-yr	50-yr	100-yr
Bunut River	1,139	2,111	2,597	3,083	4,493	5,904	5,985
Asahan River	7,673	9,780	11,573	13,303	17,693	19,462	21,231
Main stream	1,595	2,932	4,034	4,136	4,269	4,339	4,409
Silau river	6,078	6,848	7,539	9,167	13,424	15,123	16,822
Kualuh River	1,553	2,587	5,099	5,994	6,890	7,487	8,084
Mainstream	995	1,355	3,193	3,743	4,294	4,662	5,029
Kanopan river	558	1,232	1,906	2,251	2,596	2,825	3,055
Total	10,365	14,478	19,269	22,380	29,076	32,853	35,300

4.2.2 Damages under future condition

Probable flood damages under future condition in the year of AD 2005 are estimated based on the increases of property and unit value. The calculation results of probable flood damages under the future conditions are presented in Table G-40 summarizing below:

(Unit: Rp. million)

River	2-yr	5-yr	10-yr	15-yr	30-yr	50-yr	100-yr
Bunut River	1,600	3,246	4,069	4,892	7,286	9,679	9,797
Asahan River	14,471	17,991	21,006	24,804	33,904	37,620	41,299
Main stream	2,467	4,701	6,506	6,672	6,902	7,014	7,125
Silau river	12,004	13,290	14,500	18,132	27,038	30,606	34,174
Kualuh River	2,142	4,189	8,339	9,905	11,470	12,513	13,556
Mainstream	1,248	2,190	5,236	6,188	7,139	7,774	8,408
Kanopan river	894	1,999	3,103	3,717	4,331	4,739	5,148
Total	18,213	25,426	33,414	39,601	52,696	59,812	64,652

4.3 Average Annual Flood Damages

The average annual flood damages were estimated as a cumulus of flood-damages segments derived from probable flood damages multiplied by the corresponding probability of flood occurrence.

The average annual flood damages in the year of 1985 and 2005 are estimated as shown in Table G-41 and summarized below:

(Unit: Rp. million)

River	AD 1985	AD 2005
Bunut River	1,352	2,048
Asahan River	5,993	11,192
Mainstream	1,564	2,491
Silau river	4,429	8,701
Kualuh River	1,940	3,027
Mainstream	1,162	1,761
Kanopan river	778	1,266
Total	9,285	16,267

Table G.1 Annual Maximum Discharge Records

Year	Pulau Raja (Asahan R.)			Kisaran (Silau R.)			Pulo Dogom (Kualuh R.)		
	Date	W.L. (m)	Discharge (cms)	Date	W.L. (m)	Discharge (cms)	Date	W.L. (m)	Discharge (cms)
1973	-	-	-	Dec.2	3.30	590	-	-	-
1974	-	-	-	Sep.30	2.25	292	-	-	-
1975	-	-	-	May 20-21	2.00	236(260)	-	-	-
1976	-	-	-	May 21	1.97	230	-	-	-
1977	Sep.29	3.62	373(440)	Sep.30 - Oct.3	2.90	464(530)	-	-	-
1978	Dec.22	3.36	324	Dec.21	1.75	187	-	-	-
1979	Dec.13	3.10	278	Nov.20	1.80	196	-	-	-
1980	Nov. 3	3.41	333	Mar.17	1.75	187	Nov.22	3.26	450
1981	Nov.17	3.32	317	May 29	2.22	285	Oct.23	3.13	416
1982	May 23	4.18	491(460)	May 24	2.47	346(370)	Oct.18	3.31	463
1983	Sep.13	3.20	295	Dec.18	2.00	236	Dec. 8	3.60	544
1984	Jan.25	4.31	521(510)	May 24	2.10	258	Jan.25	4.02	674 (666)

Remarks ; Discharge with parentheses is estimated by runoff culculation.

Table G.2 General Features of Storage Function

Equation for drainage area

$$s = k q^{p} \quad \text{(storage equation)}$$

$$r - q = ds/dt \quad \text{(continuity equation)}$$

$$Q = 1/3.6\ f_1 A q_1 (t + T_1) + 1/3.6\ (1 - f_1) A q_2 (t + T_1) + Q_B$$

where ; Q : runoff from a drainage area (cms)

Q_B : base flow (cms)

A : drainage area (sq.km)

f_1 : primary runoff percentage

T_1 : lag time (hr)

q_1, q_2 : specific discharge from the primary or saturation area (mm/hr)

r : rainfall intensity (mm/hr)

s : storage in a drainage area (mm)

k, p : coefficients

Equation for a channel

$$S = k O^{p} - T_1 O \quad \text{(storage equation)}$$

$$I - O = ds/dt \quad \text{(continity equation)}$$

$$Q(t) = O(t - T_1)$$

where ; Q : runoff from a channel exit (cms)

O : discharge in a channel (cms)

I : inflow to a channel (cms)

S : storage in a channel (cms.hr)

Table G.3 Storage Function for Sub-basins of Asahan and Silau Rivers (1/2)

Sub-basin No.	Drainage area (km2)	Coefficient K	P	f1	Lag-time (hr)
Asahan river	5702.1				
100	3674.0	-	-	-	-
101	146.0	57.46	0.333	1.0	0.591
102	68.0	58.01	0.331	1.0	0.419
103	107.9	50.72	0.367	1.0	1.087
104	168.7	27.89	0.587	1.0	1.911
105	139.9	43.99	0.411	1.0	2.028
106	153.8	39.04	0.451	1.0	2.038
107	28.0	23.55	0.670	1.0	0.226
108	197.1	22.65	0.691	1.0	1.198
109	96.7	11.40	1.000	1.0	0.398
110	233.8(74.5)	11.40	1.000	1.0	1.648(0.911)
111	233.5(195.3)	11.40	1.000	1.0	0.667
112	79.9	11.40	1.000	1.0	0.292
113	227.4	11.40	1.000	1.0	1.436
114	147.4	11.40	1.000	1.0	0.439
(124)	(159.3)	(11.40)	(1.000)	(1.0)	(0.737)
(125)	(85.1)	(15.12)	(0.810)	(1.0)	(1.066)
(126)	(289.5)	(11.40)	(1.000)	(1.0)	(1.420)

Remarks ; Data with parentheses are used for floodway scheme which is discussed in APPENDIX H.

Table G.3 Storage Function for Sub-basins of Asahan and Silau Rivers (2/2)

Sub-basin No.	Drainage area (km2)	Coefficient K	Coefficient P	Coefficient f1	Lag-time (hr)
Silau river	1,201.4				
115	136.1	56.87	0.336	1.0	0.935
116	125.4	27.45	0.594	1.0	1.259
117	65.5	23.11	0.680	1.0	0.915
118	184.1	60.10	0.322	1.0	0.753
119	181.1	47.32	0.388	1.0	0.940
120	227.4	25.14	0.637	1.0	1.360
121	85.4	24.17	0.657	1.0	1.147
122	45.2	15.09	0.949	1.0	0.368
123	151.2	11.40	1.000	1.0	1.264

Table G.4 Discharge - Storage Relation of Existing Channel of Asahan and Silau Rivers (1/2)

Channel 1		Channel 2		Channel 3		Channel 4		Channel 5	
Q	S	Q	S	Q	S	Q	S	Q	S
0	0	0	0	0	0	-	-	-	-
14	125	18	80	50	75	-	-	-	-
50	270	50	165	100	120	-	-	-	-
100	410	100	240	200	180	-	-	-	-
200	630	200	350	300	225	-	-	-	-
260	750	340	478	400	270	-	-	-	-
400	1020	500	730	500	310	-	-	-	-
500	1200	700	980	700	400	-	-	-	-
700	1550	1000	1300	950	500	-	-	-	-
1000	1980	1500	1800	1300	730	-	-	-	-
1500	2600	2000	2200	2000	990	-	-	-	-

Channel 6		Channel 7		Channel 8		Channel 9		Channel 10	
Q	S	Q	S	Q	S	Q	S	Q	S
-	-	-	-	-	-	0	0	0	0
-	-	-	-	-	-	30	250	30	280
-	-	-	-	-	-	50	340	50	380
-	-	-	-	-	-	100	510	100	580
-	-	-	-	-	-	200	790	200	900
-	-	-	-	-	-	300	1020	300	1150
-	-	-	-	-	-	500	1440	480	1520
-	-	-	-	-	-	700	1960	700	2260
-	-	-	-	-	-	1000	2700	1000	3100
-	-	-	-	-	-	1500	3800	1500	4300
-	-	-	-	-	-	2000	4700	2000	5180

Remarks ; Q : Discharge (m3/s)

S : Storage (m^3/s.hr)

Table G.4 Discharge - Storage Relation of Existing Channel of Asahan and Silau Rivers (2/2)

Channel 11		Channel 12		Channel 13		Channel 14		Channel 15	
Q	S	Q	S	Q	S	Q	S	Q	S
0	0	0	0	0	0	0	0	0	0
40	176	30	360	40	185	30	245	30	392
50	200	50	490	50	210	50	330	50	530
100	310	100	740	100	325	100	500	100	800
200	470	200	1130	200	490	200	770	200	1220
300	600	300	1450	300	630	300	980	300	1560
500	830	500	2000	500	860	500	1320	400	2500
700	1030	700	2400	700	1060	590	1460	500	3650
1000	1470	1000	3000	1000	1400	900	2000	700	6200
1500	2050	1500	4050	1500	2100	1400	3150	1000	9500
2000	2600	2000	4850	2000	2650	2000	4250	1500	14000

Channel 16		Channel 17		Channel 18	
Q	S	Q	S	Q	S
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Table G.5 Assumed Existing Channel Condition of Asahan and Silau Rivers

River	No.	Length (km)	Slope	Manning n	Low-water Channel Depth (m)	Low-water Channel Width (m)	Channel Width (m)
Asahan							
Asahan	1	18.0	1/1300	0.030	3.0	50	80
Sakur	2	11.5	1/800	0.030	3.0	50	100
Asahan	3	2.8	1/4000	0.030	3.5	100	200
Asahan	4	-	-	-	-	-	-
Asahan	5	-	-	-	-	-	-
Asahan	6	-	-	-	-	-	-
Asahan	7	-	-	-	-	-	-
Asahan	8	-	-	-	-	-	-
Silau							
Piasa	9	33.8	1/200	0.040	3.0	50	100
Piasa	10	26.2	1/600	0.035	3.0	70	140
Silau	11	25.4	1/60	0.050	3.0	50	100
Silau	12	30.3	1/700	0.035	3.0	80	100
Silau	13	14.7	1/500	0.030	3.0	100	200
Silau	14	14.7	1/1700	0.030	3.0	120	250
Silau	15	21.7	1/1430	0.030	1.7	130	-
Silau	16	-	-	-	-	-	-
Silau	17	-	-	-	-	-	-
Silau	18	-	-	-	-	-	-

Table G.6 Probable Peak Flood Discharges of Asahan and Silau Rivers under Existing Condition

(Unit : m3/s)

Site	Return Period (year)						
	2	5	10	15	30	50	100
Asahan River							
Regulation dam	315	400	400	400	400	400	400
Proposed site of Parhitean dam	394	562	650	698	807	899	1,033
Before join Sakur R.	512	675	810	882	1,061	1,182	1,403
Pulau Raja	625	826	1,001	1,106	1,355	1,523	1,839
After join Teluk R.	703	848	1,022	1,127	1,377	1,546	1,861
Flood area							
Inflow	904	1,001	1,081	1,187	1,437	1,607	1,923
Outflow	391	429	436	440	447	453	460
After join Kepayang R.	402	440	448	452	459	464	471
After join Silau R.	753	797	810	816	828	835	861
Silau River							
Kisaran	449	457	565	670	911	1,055	1,300
Tanjung Balai	362	369	375	403	463	490	532
Tributaries							
Sakur River	113	157	220	253	326	374	448
Masihi & Teluk Rivers	136	140	143	145	147	149	151
Nantalu & Lebah R.	140	142	143	144	145	145	146
Sukaraja River	106	106	106	106	109	116	124
Max. Flooding W.Level							
Asahan River (EL,m)	3.59	4.07	4.08	4.09	4.10	4.11	4.13
Silau River (EL,m)	3.52	3.56	3.59	3.75	4.07	4.22	4.45

Table G-7 Probable Peak Flood Discharges of Asahan and Silau Rivers (1/2)

(Unit : m3/s)

Site	30-year flood		
	Alternative 1	Alternative 2	Alternative 3
Asahan River			
Regulation dam	400	400	400
Parhitean dam			
Inflow	807	807	807
Outflow	500	500	500
Before join Sakur R.	753	753	753
Pulau Raja	1,067	1,067	1,067
Floodway	591	-	-
After join Masihi R.	547	935	935
After join Nantalu R.	524	-	974
After join Sukaraja R.	598	1,015	1,083
After join Lebah R.	620	-	1,085
Retarding basin			
Inflow	-	1,127	-
Outflow	-	726	-
After join Kepayong R.	626	739	1,071
After join Silau R.	1,266	1,322	1,592
Silau River			
Kisaran	911	911	911
Tributaries			
Sakur River	326	326	326
Masihi & Teluk R.	147	147	147
Nantalu River	29	88	88
Sukaraja River	109	109	109
Lebah River	53	45	61
Retarding basin			
Max W.L (EL.m)	-	3.04	-
Max Area (km2)	-	94.2	-
Max Vol. (MCM)	-	91.6	-

Remarks ;

Alternative 1
- Asahan R.: channel improvement combined with floodway
- Silau R. : channel improvement

Alternative 2
- Asahan R.: channel improvement combined with retarding basin
- Silau R. : channel improvement

Alternative 3
- Asahan R.: channel improvement
- Silau R. : channel improvement

Table G-7 Probable Peak Flood Discharges of Asahan and Silau Rivers (2/2)

Alternative 2

(Unit : m3/s)

Site	Urgent plan			Long-term plan		
	5-yr	10-yr	15-yr	15-yr	30-yr	50-yr
Asahan River						
Regulation dam	400	400	400	400	400	400
Parhitean dam						
Inflow	562	650	698	698	807	899
Outflow	562	650	698	500	500	600
Before join Sakur R.	675	810	882	690	753	896
Pulau Raja	826	1,001	1,106	941	1,067	1,250
Retarding basin						
Inflow	948	1,044	1,106	1,057	1,127	1,250
Outflow	705	719	723	720	726	734
After join Kepayong R.	718	732	736	733	739	747
After join Silau R.	1,169	1,171	1,198	1,192	1,322	1,475
Silau River						
Kisaran	469	565	670	670	911	1,055
Tributaries						
Sakur River	157	220	253	253	326	374
Masihi & Teluk R.	140	143	145	145	147	149
Nantalu River	86	87	87	87	88	88
Sukaraja River	106	106	106	106	109	116
Lebah River	43	43	44	44	45	47
Retarding basin						
Max W.L (EL.m)	2.93	3.00	3.02	3.01	3.04	3.07
Max Area (km2)	89.1	92.0	93.4	92.4	94.2	96.6
Max Vol. (MCM)	82.5	87.5	90.0	88.2	91.6	96.3

Table G-8 Discharge - Storage Relation of Improved Channel of Asahan and Silau Rivers (1/5)

Channel 1		Channel 2		Channel 3		Channel 4		Channel 5	
Q	S	Q	S	Q	S	Q	S	Q	S
Alternative 1									
0	0	0	0	0	0	0	0	0	0
14	125	18	80	50	75	50	230	50	145
50	270	50	165	100	120	100	350	100	220
100	410	100	240	200	180	300	690	250	370
200	630	200	350	300	225	500	1550	500	1200
260	750	340	478	400	270	600	2050	700	1650
400	1020	500	730	500	310	800	2600	1000	2250
500	1200	700	980	700	400	1000	3150	1500	3000
700	1550	1000	1300	950	500	1500	4250		
1000	1980	1500	1800	1300	730				
1500	2600	2000	2200	2000	990				
Alternative 2									
Same as Alternative 1		Same as Alternative 1		Same as Alternative 1		0	0	-	-
						50	380	-	-
						100	570	-	-
						300	1150	-	-
						500	2500	-	-
						600	3400	-	-
						800	4300	-	-
						1000	5400	-	-
						1500	7400	-	-
Alternative 3									
Same as Alternative 1		Same as Alternative 1		Same as Alternative 1		Same as Alternative 2		Same as Alternative 2	

Remarks ; Q : Discharge (m3/s)
S : Storage (m3/s.hr)

Table G-8 Discharge - Storage Relation of Improved Channel of Asahan and Silau Rivers (2/5)

Channel 6		Channel 7		Channel 8		Channel 9		Channel 10	
Q	S	Q	S	Q	S	Q	S	Q	S
Alternative 1									
0	0	0	0	0	0	0	0	0	0
50	315	50	330	50	340	30	250	30	280
100	480	100	490	100	520	50	340	50	380
270	860	200	740	220	840	100	510	100	580
550	2800	300	970	450	2900	200	790	200	900
800	3900	400	1520	600	3800	300	1020	300	1150
1000	4700	500	2180	800	5000	500	1440	480	1520
1500	6400	600	2950	1000	5800	700	1960	700	2260
		700	3450	1500	8000	1000	2700	1000	3100
		1000	4750	2000	9800	1500	3800	1500	4300
		1500	6550			2000	4700	2000	5180
		2000	8200						
Alternative 2									
0	0	-	-	-	-	Same as Alternative 1		Same as Alternative 1	
50	320	-	-	-	-				
100	490	-	-	-	-				
320	990	-	-	-	-				
500	2000	-	-	-	-				
630	2900	-	-	-	-				
800	3600	-	-	-	-				
1000	4300	-	-	-	-				
1500	5500	-	-	-	-				
		-	-	-	-				
		-	-	-	-				

Table G-8 Discharge - Storage Relation of Improved Channel of Asahan and Silau Rivers (3/5)

Channel 6		Channel 7		Channel 8		Channel 9		Channel 10	
Q	S	Q	S	Q	S	Q	S	Q	S
Alternative 3									
-	-	0	0	Same as Alternative 2		Same as Alternative 1		Same as Alternative 1	
-	-	50	375						
-	-	100	555						
-	-	200	845						
-	-	400	1300						
-	-	500	1730						
-	-	700	2850						
-	-	1000	4300						
-	-	1500	6100						
-	-	2000	7700						
-	-								

Table G-8 Discharge - Storage Relation of Improved Channel of Asahan and Silau Rivers (4/5)

Channel 11		Channel 12		Channel 13		Channel 14		Channel 15	
Q	S	Q	S	Q	S	Q	S	Q	S
Alternative 1									
0	0	0	0	0	0	0	0	0	0
40	176	30	360	40	185	30	245	50	380
50	200	50	490	50	210	50	330	80	500
100	310	100	740	100	325	100	500	180	960
200	470	200	1130	200	490	200	770	300	1550
300	600	300	1450	300	630	300	980	500	2500
500	830	500	2000	500	860	500	1320	700	3150
700	1030	700	2400	700	1060	590	1460	1000	4000
1000	1470	1000	3000	1000	1400	900	2000	1500	5200
1500	2050	1500	4050	1500	2100	1400	3150		
2000	2600	2000	4850	2000	2650	2000	4250		
Alternative 2									
Same as Alternative 1		Same as Alternative 1		Same as Alternative 1		Same as Alternative 1		Same as Alternative 1	
Alternative 3									
Same as Alternative 1		Same as Alternative 1		Same as Alternative 1		Same as Alternative 1		Same as Alternative 1	

Table G-8 Discharge - Storage Relation of Improved Channel of Asahan and Silau Rivers (5/5)

Channel 16		Channel 17		Channel 18	
Q	S	Q	S	Q	S
Alternative 1					
0	0	0	0	0	0
50	200	50	380	50	145
100	330	100	570	100	220
200	980	200	1600	200	340
300	1400	300	2300	320	440
500	2100	500	3400	500	780
700	2650	700	4400	700	1100
1000	3400	1000	5600	1000	1400
1500	4400	1500	7200	1500	1950
Alternative 2					
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
lternative 3					
Same as Alternative 2		Same as Alternative 2		Same as Alternative 2	

Table G-9 Improved Channel Condition of Asahan and Silau Rivers

River	No.	Length (km)	Slope	Manning n	Low-water Channel Depth (m)	Low-water Channel Width (m)	Channel Width (m)
Asahan							
Asahan	1	18.0	1/1300	0.030	3.0	50	80
Sakur	2	11.5	1/800	0.030	3.0	50	100
Asahan	3	2.8	1/4000	0.030	3.5	100	200
Asahan	4	16.2 (9.7)	1/3500	0.030	3.0	85	500
Asahan	5	6.5	1/3500	0.030	3.0	70	500
Asahan	6	13.9	1/3500	0.028	3.0	85 (75)	500
Asahan	7	15.0	1/3500-1/4600	0.025	2.9	110 (80)	500
Asahan	8	9.2	1/18000	0.023	3.0	110	800
Silau							
Piasa	9	33.8	1/200	0.040	3.0	50	100
Piasa	10	26.2	1/600	0.035	3.0	70	140
Silau	11	25.4	1/60	0.050	3.0	50	100
Silau	12	30.3	1/700	0.035	3.0	80	100
Silau	13	14.7	1/500	0.030	3.0	100	200
Silau	14	14.7	1/1700	0.030	3.0	120	250
Silau	15	21.7	1/1430	0.030	1.7	130	255
Silau	16	10.0	1/2500	0.030	1.5	70	480
Silau	17	15.3	1/3400	0.030	1.5	90	480
Silau	18	4.7	1/3400	0.030	2.1	160	480

Remarks : Channel length and low-water channel width with parentheses is for alternative 1.

Table G-10 Estimated Flooding Condition due to Past Floods

Diffusion-type Flooding Area

Flood	Asahan Overbank inflow (*) (m3/s)	Asahan Width (m)	Asahan Depth (m)	Silau Overbank inflow (*) (m3/s)	Silau Width (m)	Silau Depth (m)
1977	239	2000	0.60	326	4000	0.48
1982	257	2000	0.63	169	2500	0.43
1984	305	5000	0.40	52	1000	0.36

(*) Peak discharge - carrying capacity (200 m /s)

Storage-type Flooding Area

Flood	Asahan W.L (El.m)	Asahan Area (km2)	Asahan Volume (10 m3)	Silau W.L (El.m)	Silau Area (km2)	Silau Volume (10 m3)
1977	3.12	133.6	81.3	3.58	12.4	13.1
1982	3.15	138.8	86.4	3.22	9.3	8.9
1984	3.64	191.7	172.8	3.03	7.6	6.6

Table G-11 Estimated Flooding Condition due to Probable Floods

Diffusion-type Flooding Area

Return Period (yr)	Asahan Overbank (*) inflow(m3/s)	Asahan Width (km)	Silau Overbank (*) inflow(m3/s)	Silau Width (km)
100	1639	13.7	1100	12.5
50	1323	11.1	855	9.7
30	1155	9.7	711	8.1
15	906	7.6	470	5.3
10	801	6.7	365	4.1
5	626	5.2	257	2.9
2	425	3.6	249	2.8

(*) Paek discharge - Carrying capacity (200 m3/s)

Storage-type Flooding Area

Return Period (yr)	Asahan Max. W.L (El.m)	Asahan Max.Area (km2)	Asahan Max.Volume (10 m6)	Silau Max.W.L (El.m)	Silau Max.Area (km2)	Silau Max.Volume (10 m6)
100	4.13	243.2	270.3	4.45	21.7	28.0
50	4.11	241.6	265.4	4.22	18.7	22.8
30	4.10	240.9	263.1	4.07	16.9	19.6
15	4.09	239.8	259.9	3.75	13.8	15.0
10	4.08	239.3	258.1	3.59	12.5	13.2
5	4.07	238.2	254.8	3.56	12.2	12.9
2	3.59	186.1	164.0	3.52	11.9	12.4

Table G-12 Storage Function for Sub-basins of Kualuh River

Sub-basin No.	Drainage area (km2)	Coefficient K	P	f1	Lag-time (hr)
201	529.6	37.82	0.395	1.0	2.402
202	58.6	21.20	0.622	1.0	1.016
203	459.4	34.85	0.421	1.0	1.006
204	292.8	33.08	0.439	1.0	2.088
205	381.5	40.73	0.373	1.0	1.431
206	70.7	29.77	0.477	1.0	0.793
207	71.6	12.51	0.940	1.0	0.920
208	235.2	32.32	0.447	1.0	1.016
209	52.6	11.40	1.000	1.0	0.201
210	194.8	11.40	1.000	1.0	1.162
211	148.0	21.41	0.617	1.0	0.823
212	75.1	15.08	0.812	1.0	0.591
213	134.2	11.40	1.000	1.0	0.748
214	117.1	24.72	0.551	1.0	0.960
215	306.6	11.40	1.000	1.0	1.572
216	375.4	11.40	1.000	1.0	2.018
217	85.1	15.12	0.810	1.0	1.066
218	224.8	11.40	1.000	1.0	1.274
219	96.3	11.40	1.000	1.0	0.829
Total	3909.4				

Table G-13 Discharge - Storage Relation of Existing Channel of Kualuh River

Channel 1		Channel 2		Channel 3		Channel 4		Channel 5		Channel 6	
Q	S	Q	S	Q	S	Q	S	Q	S	Q	S
0	0	0	0	0	0	0	0	0	0	0	0
50	460	30	135	30	350	50	340	30	120	50	490
100	700	50	185	50	470	100	520	50	170	100	740
200	1100	100	280	100	700	170	720	105	260	220	1200
300	2300	300	540	300	1350	300	1950	360	3200	500	5600
500	6400	500	730	450	1750	430	3700	500	4100	700	10500
800	16000	700	900	700	2450	700	5400	850	6200	950	18500
1000	19000	1000	1100	1000	3250	1000	7100	1000	6800	1500	25000
		2000	1700	2000	5400	2000	11500	2000	10800	2000	30500

Channel 7		Channel 8		Channel 9		Channel 10		Channel 11		Channel 12	
Q	S	Q	S	Q	S	Q	S	Q	S	Q	S
0	0	0	0	0	0	0	0	0	0	0	0
20	100	20	250	20	290	50	2900	20	240	30	450
30	140	40	400	30	550	100	4400	30	420	50	620
50	240	70	900	50	1500	300	8400	50	1100	100	910
70	350	100	1500	100	5600	500	12000	100	4200	170	1200
100	460	300	7000	140	10500	700	17000	150	8800	340	7500
200	760	450	12000	500	25000	1000	25000	500	20000	630	13500
300	1000	700	16000	1000	38000	1500	35000	1000	31000	1000	19500
500	1400	1000	20000	2000	59000	2000	42000	2000	48000	2000	32500

Remarks ; Q : Discharge (m3/s)
S : storage (m3/s.hr)

Table G-14 Assumed Existing Channel Condition of Kualuh and Kiri Rivers

River	No.	Length (km)	Slope	Manning n	Low-water Channel Depth (m)	Low-water Channel Width (m)	Channel Width (m)
Kualuh R.							
	1	26.4	1/1900	0.035	3.0	50	2000
	2	49.3	1/70	0.040	3.0	10	10
	3	20.6	1/1600	0.035	3.0	100	150
	4	21.6	1/2400	0.030	3.0	40	500
	5	10.5	1/2600	0.035	3.0	30	1000
	6	24.3	1/4500	0.028	3.5	50	2500
	7	15.9	1/2200	0.035	2.0	15	50
	8	20.9	1/8100	0.028	2.5	20	2000
	9	37.2	1/9300	0.030	3.0	10	1000
	10	53.5	1/13400	0.025	4.0	120-4000	2500-4000
	11	31.3	1/8000	0.030	3.0	10	1000
	12	22.5	1/10000	0.030	4.0	50	1000
Kiri R.							
	1	12.4	1/620	0.035	3.0	10	20
	2	13.1	1/1200	0.035	2.5	10	1000
	3	8.2	1/2800	0.030	2.0	20	1000
	4	9.4	1/310	0.035	3.0	10	20
	5	13.1	1/440	0.035	3.0	10	20
	6	10.0	1/2000	0.030	2.5	10	500
	7	18.0	1/820	0.035	3.0	10	20
	8	4.8	1/1600	0.035	2.5	10	500
	9	15.2	1/6300	0.025	4.0	60	300
	10	12.6	1/4200	0.030	3.0	30	80

Table G-15 Storage Function for Sub-basins of Kiri River

Sub-basin No.	Drainage area (km2)	Coefficient K	P	f1	Lag-time (hr)
301	86.1	22.87	0.636	1.0	1.350
302	30.6	17.27	0.793	1.0	0.317
303	65.0	14.99	0.886	1.0	0.444
304	112.3	16.30	0.829	1.0	1.400
305	114.2	25.55	0.583	1.0	1.608
306	72.5	21.16	0.676	1.0	0.965
307	62.6	21.10	0.678	1.0	0.656
308	21.7	11.40	1.000	1.0	0.196
309	55.7	24.86	0.596	1.0	0.576
310	42.7	15.89	0.846	1.0	0.601
311	77.6	19.35	0.725	1.0	1.127
312	14.7	11.40	1.000	1.0	0.176
313	39.2	11.40	1.000	1.0	0.333
314	72.6	11.40	1.000	1.0	1.127
Total	867.5				

Table G-16 Discharge - Storage Relation of Existing Channel of Kiri River

Channel 1		Channel 2		Channel 3		Channel 4		Channel 5	
Q	S	Q	S	Q	S	Q	S	Q	S
0	0	0	0	0	0	0	0	0	0
30	60	20	60	20	40	30	35	30	60
50	80	40	100	50	130	50	50	80	105
70	100	100	350	100	340	100	80	150	190
120	170	200	920	200	880	300	200	300	330
200	260	300	1600	400	2300	500	300	500	460
500	500	500	3300	600	3000	700	370	700	570
700	630	700	4400	800	3500	1000	480	1000	720
1000	810	1000	5400	1000	4100				

Channel 6		Channel 7		Channel 8		Channel 9		Channel 10	
Q	S	Q	S	Q	S	Q	S	Q	S
0	0	0	0	0	0	0	0	0	0
20	50	30	95	30	30	20	200	30	160
30	60	60	150	50	60	50	340	50	210
50	120	100	240	100	170	100	520	100	330
100	360	200	420	250	650	200	780	200	700
250	1500	500	800	400	900	300	1000	500	1550
400	2000	700	1000	600	1200	500	2300	700	2050
600	2600	1000	1300	800	1400	700	3200	1000	2750
800	3100			1000	1600	1000	4400		

Remarks ; Q : Discharge (m3/s)
S : storage (m3/s.hr)

Table G-17 Probable Peak Flood Discharges of Kualuh and Kiri Rivers under Existing Condition (1/2)

(Unit : m3/s)

Site	Return Period (year)						
	2	5	10	15	30	50	100
Kualuh River							
Pulo Dogom	661	729	880	978	1101	1270	1378
Guntung Saga Atas	657	673	795	885	1001	1170	1299
After join Simangalam River	547	575	605	676	765	877	967
After join Natas R.	760	791	828	914	1022	1155	1265
After join Kanopan R.	669	691	705	714	734	782	822
After join Kuo R.	698	719	732	741	769	816	857
After join Leidong R.	747	772	789	799	812	828	849
Kiri River							
Bunut	51	63	70	73	80	88	95
Desa Gajah	77	92	101	105	113	121	129
After join Silau Tua River	197	231	253	266	287	307	325
After join Balai R.	251	294	321	338	364	390	413
After join Kanan R.	290	339	353	366	389	412	433

Table G-17 Probable Peak Flood Discharges of Kualuh and Kiri Rivers under Existing Condition (2/2)

(Unit : m3/s)

Site	Return Period (year)						
	2	5	10	15	30	50	100
<u>Tributaries</u>							
Tembus R.	221	265	324	362	411	468	521
Simangalam R.	110	111	111	111	112	112	115
Natas R.	214	218	226	240	258	279	299
Kanopan R.	82	82	83	83	83	84	84
Kuo R.	43	43	43	43	43	44	44
Leidong R.	54	54	54	54	54	54	54
Silau Tua R.	78	93	102	108	117	125	132
Balai R.	57	67	74	78	85	92	98
Kanan R.	34	41	46	48	53	57	61

Table G-18 Probable Peak Flood Discharge of Kualuh and Kiri Rivers (with Channel Improvement)

Kualuh River

Site	Peak Discharge (m3/s)
Main Stream	
Pulo Dogon	1101
Guntung Saga Atas	1001
After join Simangalam R.	797
After join Natas R.	1055
After join Kanopan R.	1006
After join Kuo R.	1036
After join Leidong R.	930
Tributaries	
Tembus R.	411
Simangalam R.	112
Natas R.	258
Kanopan R.	118
Kuo R.	43
Leidong R.	54

Kiri River

Site	Peak Discharge (m3/s)
Main Stream	
Bunut	80
Desa Gajah	110
After join Silau Tua R.	298
After join Balai R.	377
After join Kanopan R.	394
Tributaries	
Silau Tua R.	117
Balai R.	85
Kanan R.	53

Remarks ; Probability of rainfall volume is taken up for 30-year return period.

Table G-19 Discharge - Storage Relation of Improved Channel of Kualuh River

Channel 1		Channel 2		Channel 3		Channel 4		Channel 5		Channel 6	
Q	S	Q	S	Q	S	Q	S	Q	S	Q	S
0	0	0	0	0	0	0	0	0	0	0	0
50	460	30	135	30	350	50	250	30	120	50	210
100	700	50	185	50	470	100	380	50	170	100	330
200	1100	100	280	100	700	200	580	105	260	300	640
300	2300	300	540	300	1350	400	1900	360	3200	500	1800
500	6400	500	730	450	1750	600	3700	500	4100	750	4000
800	16000	700	900	700	2450	800	4600	850	6200	1000	5000
1000	19000	1000	1100	1000	3250	1000	5500	1000	6800	1500	7000
		2000	1700	2000	5400	2000	9000	2000	10800	2000	8700

Channel 7		Channel 8		Channel 9		Channel 10		Channel 11		Channel 12	
Q	S	Q	S	Q	S	Q	S	Q	S	Q	S
0	0	0	0	0	0	0	0	0	0	0	0
20	100	20	60	20	290	50	2700	20	240	30	450
30	140	50	100	30	550	100	4100	30	420	50	620
50	240	100	250	50	1500	200	6200	50	1100	100	910
70	350	150	380	100	5600	400	9400	100	4200	170	1200
100	460	200	500	140	10500	600	13500	150	8800	340	7500
200	760	300	670	500	25000	800	17500	500	20000	630	13500
300	1000	400	820	1000	38000	1000	21000	1000	31000	1000	19500
500	1400	500	960	2000	59000	2000	33000	2000	48000	2000	32500

Remarks ; Q : Discharge (m3/s)
S : storage (m3/s.hr)

Table G-20 Discharge - Storage Relation of Improved Channel of Kiri River

Channel 1		Channel 2		Channel 3		Channel 4		Channel 5	
Q	S	Q	S	Q	S	Q	S	Q	S
0	0	0	0	0	0	0	0	0	0
30	60	20	60	20	40	30	35	30	60
50	80	40	100	50	150	50	50	80	105
70	100	60	180	100	420	100	80	150	190
120	170	80	280	150	620	300	200	300	330
200	260	110	450	200	750	500	300	500	460
500	500	200	700	300	1000	700	370	700	570
700	630	300	950	500	1400	1000	480	1000	720
1000	810	500	1300	1000	2100				

Channel 6		Channel 7		Channel 8		Channel 9		Channel 10	
Q	S	Q	S	Q	S	Q	S	Q	S
0	0	0	0	0	0	0	0	0	0
20	50	30	95	30	30	20	200	30	160
30	60	60	150	50	60	50	340	50	210
50	120	100	240	100	170	100	520	100	330
100	360	200	420	250	650	200	780	200	700
250	1500	500	800	400	900	300	1000	500	1550
400	2000	700	1000	600	1200	500	2300	700	2050
600	2600	1000	1300	800	1400	700	3200	1000	2750
800	3100			1000	1600	1000	4400		

Remarks ; Q : Discharge (m3/s)
S : storage (m3/s.hr)

Table G-21 Improved Channel Condition of Kualuh and Kiri Rivers

River	No.	Length (km)	Slope	Manning n	Low-water Channel Depth (m)	Low-water Channel Width (m)	Channel Width (m)
Kualuh R.							
	1	26.4	1/1900	0.035	3.0	50	2000
	2	49.3	1/70	0.040	3.0	10	10
	3	20.6	1/1600	0.035	3.0	100	150
	4	17.7	1/1600	0.030	3.0	40	600
	5	10.5	1/2600	0.035	3.0	30	1000
	6	12.6	1/2500	0.028	3.5	50	1000
	7	15.9	1/2200	0.035	2.0	15	50
	8	7.6	1/3700	0.028	2.5	20	100
	9	37.2	1/9300	0.030	3.0	10	1000
	10	47.4	1/13400	0.025	4.0	120-4000	2500-4000
	11	31.3	1/8000	0.030	3.0	10	1000
	12	22.5	1/10000	0.030	4.0	50	1000
Kiri R.							
	1	12.4	1/620	0.035	3.0	10	20
	2	13.1	1/1200	0.035	2.5	10	100
	3	8.2	1/2800	0.030	2.0	20	200
	4	9.4	1/310	0.035	3.0	10	20
	5	13.1	1/440	0.035	3.0	10	20
	6	10.0	1/2000	0.030	2.5	10	500
	7	18.0	1/820	0.035	3.0	10	20
	8	4.8	1/1600	0.035	2.5	10	500
	9	15.2	1/6300	0.025	4.0	60	300
	10	12.6	1/4200	0.030	3.0	30	80

Table G-22 Estimated Flood Damage of Past Floods (1/2)

1. Asahan river

Item	Unit	Flood		
		Sep.1977	May 1982	Jan.1984
1) Inundated area				
House/building	nos.	562	565	1249
Paddy	ha	1980	2010	2740
Uplands crops	"	30	150	570
Oil palm	"	-	-	-
Rubber	"	-	-	-
Others(including swamp)	"	13690	14340	22390
Total	"	15700	16500	25700
2) Average inundated depth				
House/building	m	0.50	0.50	0.64
Paddy	"	0.60	0.60	0.74
Upland crops	"	0.40	0.40	0.50
Oil palm	"	-	-	-
Rubber	"	-	-	-
Others	"	0.50	0.50	0.64
3) Maximum inundated depth				
House/building	m	1.40	1.40	1.90
Paddy	"	1.62	1.65	2.14
Upland crops	"	0.50	0.50	0.55
Oil palm	"	-	-	-
Rubber	"	-	-	-
Others	"	1.40	1.40	1.90
4) Inundated duration	day	5	81	69
5) Peak discharge at Pulau Raja	cms	450	486	512

Note : based on the computation results on the topographic map and field survey.

Table G-22 Estimated Flood Damage of Past Floods (2/2)

2. Silau river

I t e m	Unit	Flood		
		Sep.1977	May 1982	May 1984
1) Inundated area				
House/building	nos.	7300	3860	3405
Paddy	ha	4658	3036	1329
Upland crops	"	46	30	30
Oil palm	"	100	-	-
Rubber	"	101	-	-
Others	"	855	527	459
Total	"	5760	3593	1818
2) Average inundated depth				
House/building	m	0.60	0.57	0.50
Paddy	"	0.70	0.60	0.60
Uplands crops	"	0.50	0.50	0.50
Oil palm	"	0.50	-	-
Rubber	"	0.50	-	-
Others	"	0.60	0.57	0.50
3) Maximum inundated depth				
House/building	m	1.58	1.22	0.85
Paddy	"	1.83	1.47	1.10
Upland crops	"	1.08	1.00	0.80
Oil palm	"	0.50	-	-
Rubber	"	0.50	-	-
Others	"	1.58	1.22	0.85
4) Inundated duration	day	6	4	8
5) Peak discharge at Kisaran	cms	570	420	310

Note : based on the computation results on the topographic map and field survey.

Table G-23 Estimated Flood Damage of Probable Floods (1/5)

1. Bunut river

I t e m	Unit	Probable Flood			
		2-yr	10-yr	30-yr	100-yr
1) Inundated area					
House/building	nos.	759	1710	2799	3589
Paddy	ha	1615	2280	3290	4150
Uplands crops	"	19	36	68	96
Oil palm	"	-	-	-	-
Rubber	"	10	90	225	355
Coconut palm	"	25	170	400	525
Others	"	81	144	217	319
Total	"	1740	2720	4200	5450
2) Average inundated depth					
House/building	m	0.75	1.10	1.40	1.70
Paddy	"	0.75	1.10	1.40	1.70
Upland crops	"	0.75	1.10	1.40	1.70
Oil palm	"	-	-	-	-
Rubber	"	0.20	0.45	0.75	1.50
Coconut palm	"	0.75	0.90	1.05	1.25
Others	"	0.75	1.10	1.40	1.70
3) Maximum inundated depth					
House/building	m	0.80	1.15	1.45	1.75
Paddy	"	1.10	1.50	1.75	2.10
Upland crops	"	0.80	1.15	1.45	1.75
Oil palm	"	-	-	-	-
Rubber	"	0.25	0.50	0.80	1.50
Coconut palm	"	0.80	1.15	1.55	1.75
Others	"	0.80	1.15	1.45	1.75
4) Inundated duration	day	2	3	4	4
5) Peak discharge at Bunut	cms	51	70	80	95

Table G-23 Estimated Flood Damage of Probable Floods (2/5)

2. Asahan river

Item	Unit	Probable Flood			
		2-yr	10-yr	30-yr	100-yr
1) Inundated area					
House/building	nos	733	1387	1441	1486
Paddy	ha	2434	4866	5103	5467
Uplands crops	"	160	876	966	1076
Oil palm	"	-	-	166	608
Rubber	"	-	-	-	-
Others (including swamp)	"	13996	23675	28925	32129
Total	"	16590	29417	35160	39280
2) Average inundated depth					
House/building	m	0.51	0.65	0.78	0.80
Paddy	"	0.61	0.75	0.88	0.90
Upland crops	"	0.50	0.50	0.51	0.52
Oil palm	"	-	-	0.50	0.50
Rubber	"	-	-	-	-
Others	"	0.51	0.65	0.78	0.80
3) Maximum inundated depth					
House/building	m	1.59	2.08	2.10	2.13
Paddy	"	1.84	2.33	2.35	2.38
Upland crops	"	0.50	0.58	0.60	0.63
Oil palm	"	-	-	0.50	0.50
Rubber	"	-	-	-	-
Others	"	1.59	2.08	2.10	2.13
4) Inundated duration	day	more than 5	more than 7	more than 7	more than 7
5) Peak discharge at Pulau Raja	cms	625	1001	1355	1839

Table G-23 Estimated Flood Damage of Probable Floods (3/5)

3. Silau river

Item	Unit	Probable Flood			
		2-yr	10-yr	30-yr	100-yr
1) Inundated area					
House/building	nos.	6350	7364	9581	11809
Paddy	ha	3270	4686	4932	5387
Upland crops	"	33	47	49	54
Oil palm	"	-	100	1092	1300
Rubber	"	-	101	1598	1805
Others	"	802	864	1754	3932
Total	"	4105	5770	9425	12478
2) Average inundated depth					
House/building	m	0.57	0.57	0.68	0.80
Paddy	"	0.67	0.67	0.78	0.90
Uplands crops	"	0.50	0.50	0.50	0.50
Oil palm	"	-	0.50	0.50	0.50
Rubber	"	-	0.50	0.50	0.50
Others	"	0.57	0.57	0.68	0.80
3) Maximum inundated depth					
House/building	m	1.52	1.59	2.07	2.25
Paddy	"	1.77	1.84	2.32	2.70
Upland crops	"	1.02	1.09	1.57	1.95
Oil palm	"	-	0.50	0.50	0.50
Rubber	"	-	0.50	0.50	0.50
Others	"	1.54	1.59	2.07	2.25
4) Inundated duration	day	5	6	6	6
5) Peak discharge at Kisaran	cms	449	565	911	1300

Table G-23 Estimated Flood Damage of Probable Floods (4/5)

4. Kualuh river

I t e m	Unit	Probable Flood			
		2-yr	10-yr	30-yr	100-yr
1) Inundated area					
House/building	nos.	397	1498	2028	2557
Paddy	ha	1730	6785	8110	9430
Upland crops	"	140	345	435	530
Oil palm	"	-	-	-	-
Rubber	"	-	-	170	350
Others	"	3160	7600	8905	10190
Total	"	5030	14730	17620	20500
2) Average inundated depth					
House/building	m	0.30	0.45	0.50	0.55
Paddy	"	0.30	0.45	0.50	0.55
Uplands crops	"	0.30	0.45	0.50	0.55
Oil palm	"	-	-	-	-
Rubber	"	-	-	0.10	0.25
Others	"	0.30	0.45	0.50	0.55
3) Maximum inundated depth					
House/building	m	1.00	1.75	2.00	2.25
Paddy	"	1.00	1.75	2.00	2.25
Upland crops	"	1.00	1.75	2.00	2.25
Oil palm	"	-	-	-	-
Rubber	"	-	-	0.15	0.30
Others	"	1.00	1.75	2.00	2.25
4) Inundated duration	day	more than 7	more than 7	more than 7	more than 7
5) Peak discharge at Pulo Dogom	cms	661	880	1101	1378

Table G-23 Estimated Flood Damage of Probable Floods (5/5)

5. Kanopan river

Item	Unit	Probable Flood			
		2-yr	10-yr	30-yr	100-yr
1) Inundated area					
House/building	nos.	252	885	1089	1176
Paddy	ha	713	2310	3074	3265
Upland crops	"	23	77	185	212
Oil palm	"	-	-	-	-
Rubber	"	-	-	30	50
Others	"	1324	2333	4303	4783
Total	"	2060	4720	7592	8310
2) Average inundated depth					
House/building	m	0.40	0.55	0.70	0.75
Paddy	"	0.45	0.60	0.70	0.75
Uplands crops	"	0.45	0.50	0.55	0.60
Oil palm	"	-	-	-	-
Rubber	"	-	-	0.20	0.25
Others	"	0.40	0.55	0.70	0.75
3) Maximum inundated depth					
House/building	m	0.75	1.25	1.50	1.75
Paddy	"	1.25	1.75	2.00	2.25
Upland crops	"	0.75	1.25	1.50	1.75
Oil palm	"	-	-	-	-
Rubber	"	-	-	0.20	0.25
Others	"	0.75	1.25	1.50	1.75
4) Inundated duration	day	more than 7	more than 7	more than 7	more than 7
5) Peak discharge at Highway bridge	cms	108	109	109	110

Table G-24 Average Floor Space of House/Building in Study Area

Floor Space	Average	Urban Area				Rural Area			
(m2)	(m2)	Tg.Balai	Asahan	Total	Space(m2)	Asahan	L.Batu	Total	Space(m2)
- 19	15	217	650	967	13,005	10,686	6,200	16,886	253,290
20 - 29	25	672	856	1,528	38,200	30,612	19,048	49,660	1,241,500
30 - 39	35	648	3,035	3,683	128,905	34,690	21,437	56,127	1,964,445
40 - 49	45	884	1,956	2,840	127,800	32,210	22,504	54,714	2,462,130
50 - 69	60	2,206	1,748	3,954	237,240	15,976	14,196	30,172	1,810,320
70 - 99	85	1,396	2,638	4,034	342,890	5,963	10,812	16,775	1,425,875
100 - 149	125	373	3,183	3,556	444,500	836	2,194	3,030	378,750
150 - 199	175	150	425	575	100,625	162	227	389	68,075
200 - 299	250	117	170	287	71,750	225	145	370	92,500
300 -	300	49	52	101	30,300	548	206	754	226,200
Total	-	6,712	14,713	21,425	1,535,215	131,998	96,969	228,967	9,923,085
Ave.(m2/house)				71.66				43.34	

Source : Penduduk Sumatera Utara No.4, Hasil Sensus Penduduk 1980 ; Biro Pusat Statistik, Jakarta.

Table G-25 Unit Price of House/Building in 1985

Description	Unit Price (Rp/m2) /1	Ratio in the Area /2	Weighted Mean (Rp)
I. Urban Area			
Parmanent house	25,000	0.80	20,000
Semi-parmanent house	15,000	0.10	1,500
Small house	10,000	0.05	500
Temporary house	7,000	0.05	350
Total	-	1.00	22,350
II. Rural Area			
Parmanent house	25,000	0.15	3,750
Semi-parmanent house	15,000	0.35	5,250
Small house	10,000	0.30	3,000
Temporary house	7,000	0.20	1,400
Total	-	1.00	13,400

Note ; /1 House depreciation rate of 50 % is considered.

/2 our estimation based on the field survey and information in the Kec. Simpang Empat office.

Table G-26 Estimated Value of Household Effects in 1980

(Unit : Rp)

Paticular	Monthly Expenditure				Estimated Amount of Household Effects	
	Per Capita		Family *1			
	Urban	Rural	Urban	Rural	Urban	Rural
1. Food, beverage	7,965	6,859	45,560	36,833	1,498 *2	1,211 *2
2. Household furnishing and durable goods	343	324	1,962	1,740	353,160 *3	313,200 *3
3. Clothing and other wear	681	494	3,896	2,653	93,504 *4	63,672 *4
4. Fuel, light, water for house	2,024	660	11,577	3,544	11,577 *5	3,544 *5
5. Personal goods	1,160	457	6,635	2,454	398,100 *6	147,240 *6
6. Others(tax,contribution, ceremony, etc.)	560	193	3,203	1,036	-	-
Total	12,733	8,987	72,833	48,260	857,839	528,867

Source : Sumatera Utara Dalam Angka 1983, p.443.

Note : *1 assuming one family consists of 5.72 and 5.37 persons for the urban and rural, respectively.
*2 assuming equivalent to one-day family expenditure to these things.
*3 assuming equivalent to 15-year family expenditure to these things.
*4 assuming equivalent to 2-year family expenditure to these things.
*5 assuming equivalent to one-month family expenditure to these things.
*6 assuming equivalent to 5-year family expenditure to these things.

Table G-27 Groth Rate of Per-capita Regional Income and Consumer Price Index (CPI) in Medan

Year	Per-capita Regional Income			Consumer Price Index *2	
	1975-price (Rp)	Groth Rate *1			
		1975 =100	1980 =100	1977 =100	1980 =100
1975	76,864.37	100.0	72.5		
1976	81,731.64	106.3	77.1		
1977	88,264.28	114.8	83.3	100.0	64.1
1978	65,268.66	123.9	89.9		
1979	100,303.87	130.5	94.6		
1980	106,015.55	137.9	100.0	156.1	100.0
1981	111,640.59	145.2	105.3	174.6	111.9
1982	(116,139.46) *3	151.1	109.5	186.3	119.3
1983		160	116	209.4	134.1
1984		170	123	239	153
1985		180	130	274	176

Source : Sumatera Utara Dalam Angka, 1983.

Note : *1 assuming at 6.07 % per annum.

*2 assuming at 14.47 % per annum.

*3 preliminary estimate by the document.

Table G-28 Damage Rate of Inundation and Sedimentation for House/Building, Household Effects and Stored Goods

I. Damage Rate of Inundation

Item	Inundation depth above floor level (cm)				
	0-49	50-99	100-199	200-299	300-
House/Building	0.053	0.072	0.109	0.152	0.220
Household effects	0.086	0.191	0.331	0.499	0.690
Stored goods	0.180	0.314	0.419	0.539	0.630

II. Damage Rate of Sedimentation

Item	Sedimentation depth (cm)	
	less than 60 cm	more than 60 cm
House/Building	0.43	0.57
Household effects	0.50	0.69
Stored goods	0.54	0.63

Source : Manual for River and Sabo Works in Japan ; International Engineering Consultants Association, Japan, 1977.

Note : (1) Rate in the "less than 60 cm" is adopted for the estimation.
(2) Floor height is assumed at 10 cm for I and II.

Table G-29 Number of Houses/Buildings in Each Kecamatan and Kotamadya of Flood Prone Area

(Unit : Nos.)

Kecamatan/ Kotamadya	Residence/ Farmhouse	Store/ Trade	Small Industry	Hotel/ Restaurant	Others	Total
I. Kabupaten Asahan						
1. Pulau Rakyat	11,679	151	75	17	1,372	13,294
2. Sei. Kepayang	6,848	129	38	13	1,426	8,454
3. Kisaran	21,910	756	145	40	2,719	25,570
4. Air Batu	10,313	172	25	18	605	11,133
5. Air Joman	6,826	99	20	3	355	7,303
6. Simpang Empat	6,411	42	9	0	560	7,022
7. Tanjung Balai	11,521	198	51	1	620	12,391
Sub-total	74,788	1,610	363	92	7,657	84,510
II. Kotamadya Tanjung Balai	6,363	694	100	133	1,038	8,328
Total	81,151	2,304	463	225	8,695	92,838

Source : Penduduk Kabupaten Asahan 1980.

Table G-30 Number of Households in Each Kecamatan and Kotamadya of Flood Prone Area in 1980

Kecamatan/ Kotamadya	Population	Number of Households	Ave. Population per Household
I. Kabupaten Asahan			
1. Sei. Kepayang	36,308	7,022	5.17
2. Tanjung Balai	61,524	11,652	5.28
3. Air Joman	38,866	7,802	4.98
4. Kisaran	57,122	21,819	5.79
5. Simpang Empat	33,950	6,518	5.21
6. Air Batu	57,122	10,560	5.41
7. Pulau Rakyat	62,219	12,183	5.11
Sub-total	416,312	77,556	5.37
II. Kotamadya Tanjung Balai (*)	42,814	7,484	5.72
III. Kabupaten Labuhan Batu (*)			
1. Kualur Hilir	43,971	9,367	4.69
2. Kualuh Hulu	95,164	17,249	5.52
3. Aek Natas	42,271	8,520	4.96
Sub-total	181,406	35,136	5.16
Total	640,532	120,176	5.33

Source : 1. Penduduk Kabupaten Asahan, 1980.
2. Kotamadya Tanjung Balai Dalam Angka, 1983.
3. Penduduk Kabupaten Labuhan Batu, 1983.

Note : (*) data in 1983.

Table G-31 Estimated Value of Stored Goods in Commercial Sector in 1980

Paticular	Monthly Family Expenditure (Rp)		Monthly Expenditure in the Asahan and Silau River Areas (Rp 10^6) *1			Ratio of Purchase from Store *2	Average Monthly Income per Store *3 (Rp)	Estimated Amount of Stored Goods (Rp)
	Urban	Rural	Urban	Rural	Total			
1. Food, beverage	45,560	36,833	332.7	2,856.6	3,189.3	0.50	630,000	157,600 *4
2. Furnishing and durable goods	1,962	1,740	14.3	134.9	149.2	0.95	56,050	672,600 *5
3. Clothing and other wear	3,896	2,653	28.5	205.8	234.3	0.90	83,380	166,760 *6
4. Fuel, light, etc. for house	11,577	3,544	84.5	274.9	359.4	0.95	135.000	67,500 *7
5. Personal goods	6,635	2,454	48.5	190.3	238.8	0.90	84,980	169,960 *8
6. Others	3,203	1,036	23.4	80.4	103.8	-	-	-
Total	72,833	48,260	531.9	3,742.9	4,274.8	-	674,710	1,234,420

Note : * 1 Households in the area in 1980 is estimated at 7,303 and 77,556 for urban and rural, respectively.
* 2 our estimation based on the interview survey.
* 3 Number of commercial sector in the area is estimated at 2,529 in 1980.
* 4 assuming equivalent to one-week store income to these things.
* 5 assuming equivalent to one-year store income to these things.
* 6 assuming equivalent to 2-months store income to these things.
* 7 assuming equivalent to 2-weeks store income to these things.
* 8 assuming equivalent to 2-months store income to these things.