Fig . 2·7·2 Relation between Slope of River Bed and Distance from Divide

I: Mean Slope of River Bed
L: Distance from Divide (Km)
$I = KL^{-\beta}$
( ): Elevation

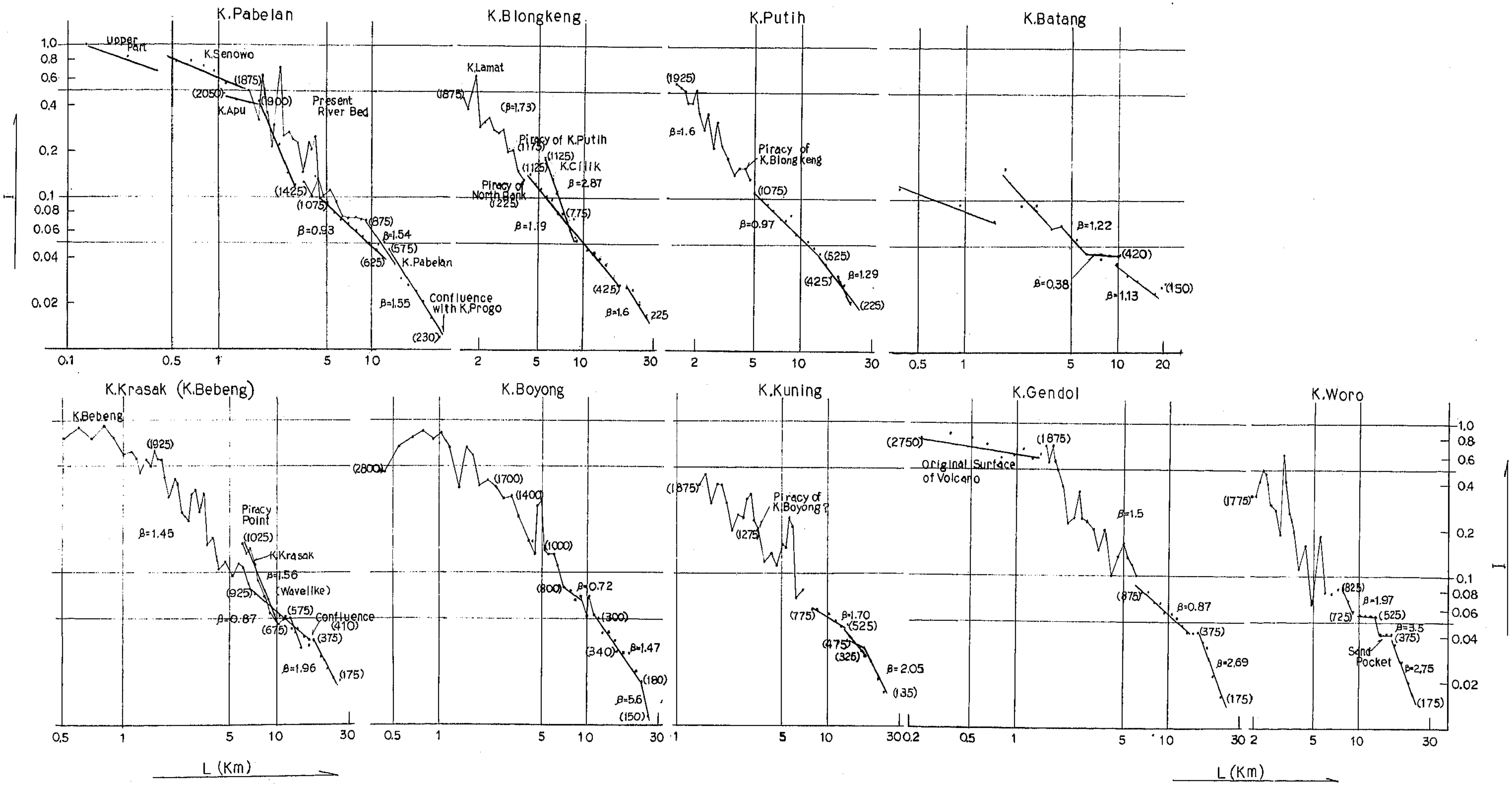


Fig. 2.7.3 Characteristics of Sediment Transportation

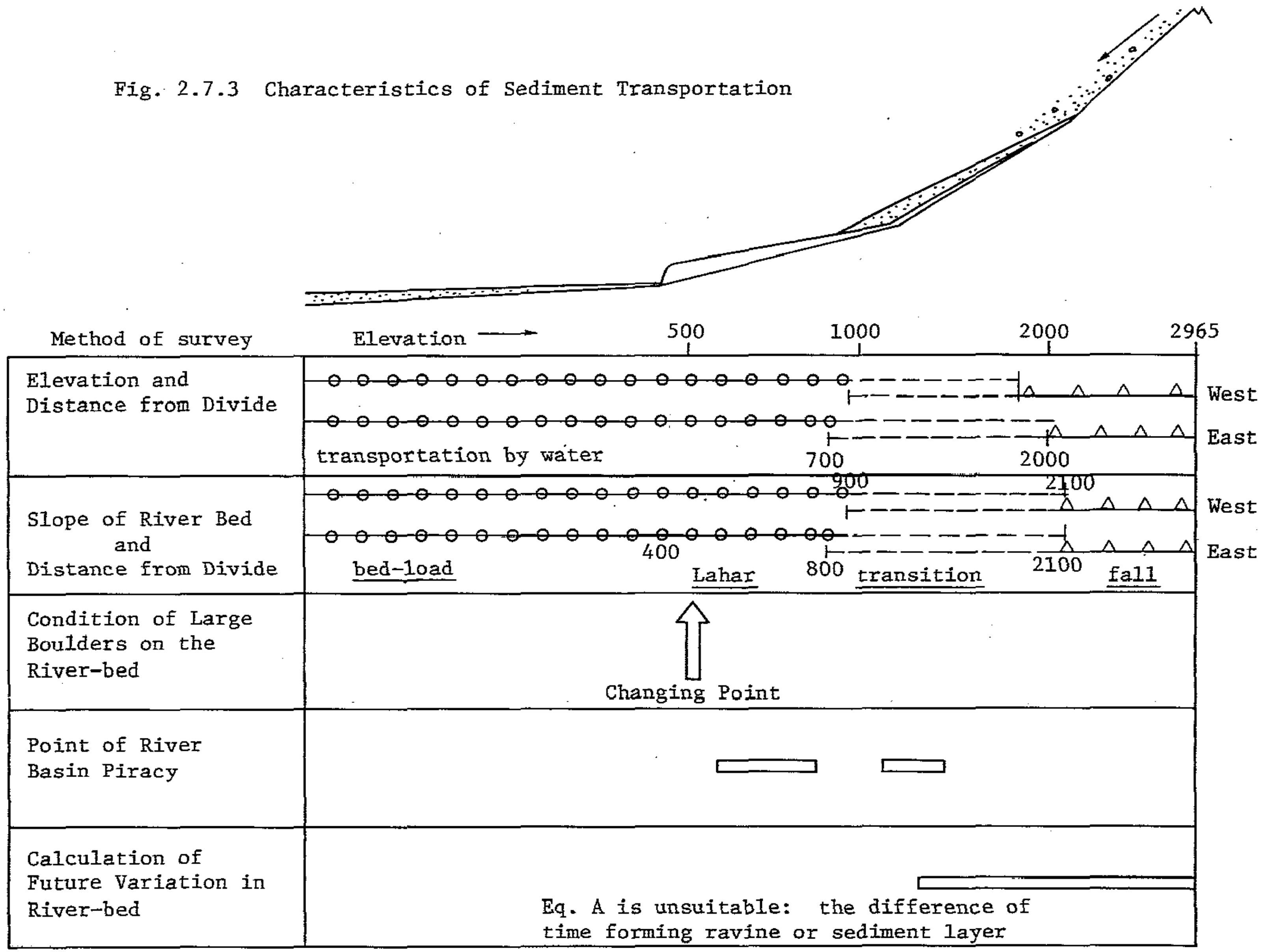
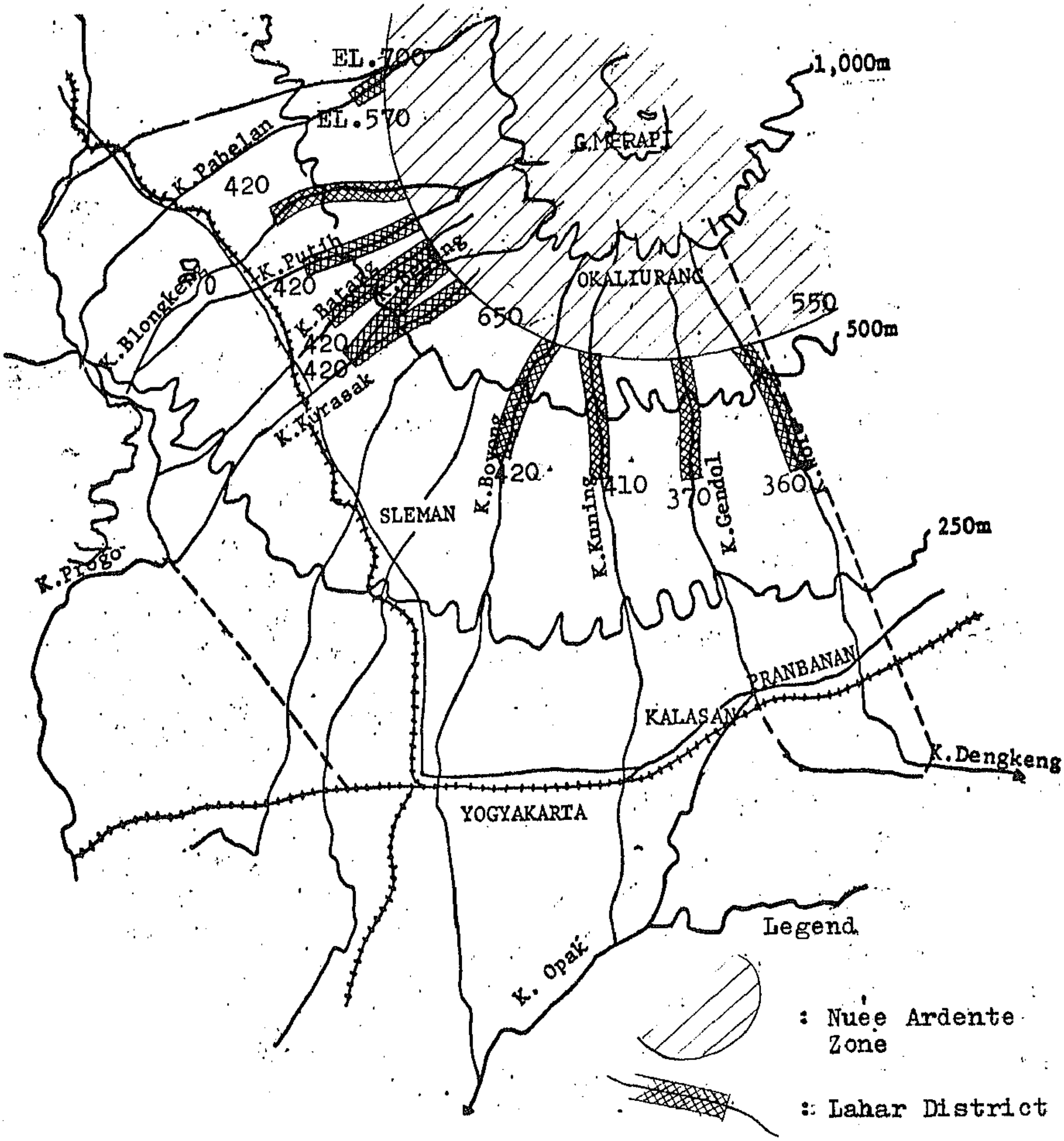


Table 2.7.1 Sharp Changing Points of the Rate of River Bed Gradient

Name of tributary	Elevation of changing point (m)	Gradient at the point (pct (deg.))
K. Pabelan	570m	4.5% (2.0°)
K. Blongkeng	420	2.6 (1.5)
K. Putih	420	3.0 (1.7)
K. Batang	420	4.3 (2.5)
K. Krasak	420	3.8 (2.2)
K. Boyong	500	5.0 (2.9)
K. Kuning	520	4.0 (2.6)
K. Gendol	370	4.2 (2.4)
K. Woro	370	4.2 (2.4)

Fig. 2.7.4 Distribution Map of Nuée Ardente and Lahar



2.7.3 Danger Areas of Lahar/Banjir Flooding

(1) Relationship of the Landform and Lahar/Banjir

When Lahar and Banjir are regarded as geomorphic stages or geological processes on the slope of G. Merapi, possible damage areas from lahar or banjir can be estimated by the geomorphic analysis. The danger areas of lahar and banjir were determined from the geomorphological land condition map that was prepared using photo interpretation (map: 1/25,000, photos: 1/40,000) and field surveys.

According to geomorphological study, there is quite close relationship between the landforms and lahar/banjir occurence. Fig. 2.7.5 shows that rivers generally overflow at the places where they turn sharply or stream gradiations change and become more gentle. These topographical changes correspond to the geological/lithological differences on the slope of G. Merapi. The landform of the volcanic slope is the result of the volcanic activity.

Usually lahar/Banjir follow old river courses, and small and shallow valleys. Today's landforms suggest the possible flooding area of lahar and banjir. The isoclinal slope map, drainage system and flow direction map have been prepared as the supplementary information. By field survey, flooding areas and the sand deposits distributed with them were studied.

(2) The Relationship of the Landform and Lahar/Banjir

According to the survey of the Lahar and Banjir in 1975 and 1976, the Landform overflow points and flooding area resulting from Lahar/Banjir are described as follows:

<u>Overflow points</u>

1) The point where the gradient of the river-bed becomes gentle (downstream of the breaking zone)

2) The point where the river course crosses a former river course.

3) The point where the river-bed is raised up by sedimentation.

4) The river terraces

5) The point at where the discharge area decreases sharply.

6) The point at where the river course bends sharply.

Flooding areas

1) Topographical small undulations and streams become the boundary of the flooding area.

2) The flood flows into a small channel or former river course after flooding.

3) In case the small channel or former river course does not have enough capacity to handle all the volume, the flood overflows these boundaries again.

4) A lot of sand transported by the flood remains along the small channel.

5) Houses are damaged and human lives disrupted in the sediment deposit area.

(3) Distribution Map for Degree of Danger of Lahar and Banjir Banjir Flooding

The results of the field surveys have given a rough idea of the relationship between lahar and banjir disasters and topographical conditions. A map has therefore been prepared which shows the degree of lahar and banjir flooding hazard in different places on the basis of a land conditions index and the relative height of banks (or cliffs).

Five degrees of danger have been determined on the basis of the relative heights of the banks for the flooding area. Where there was overlapping, the higher degree of hazard was given priority. Particularly hazardous points and old river courses and terraces have also been marked.

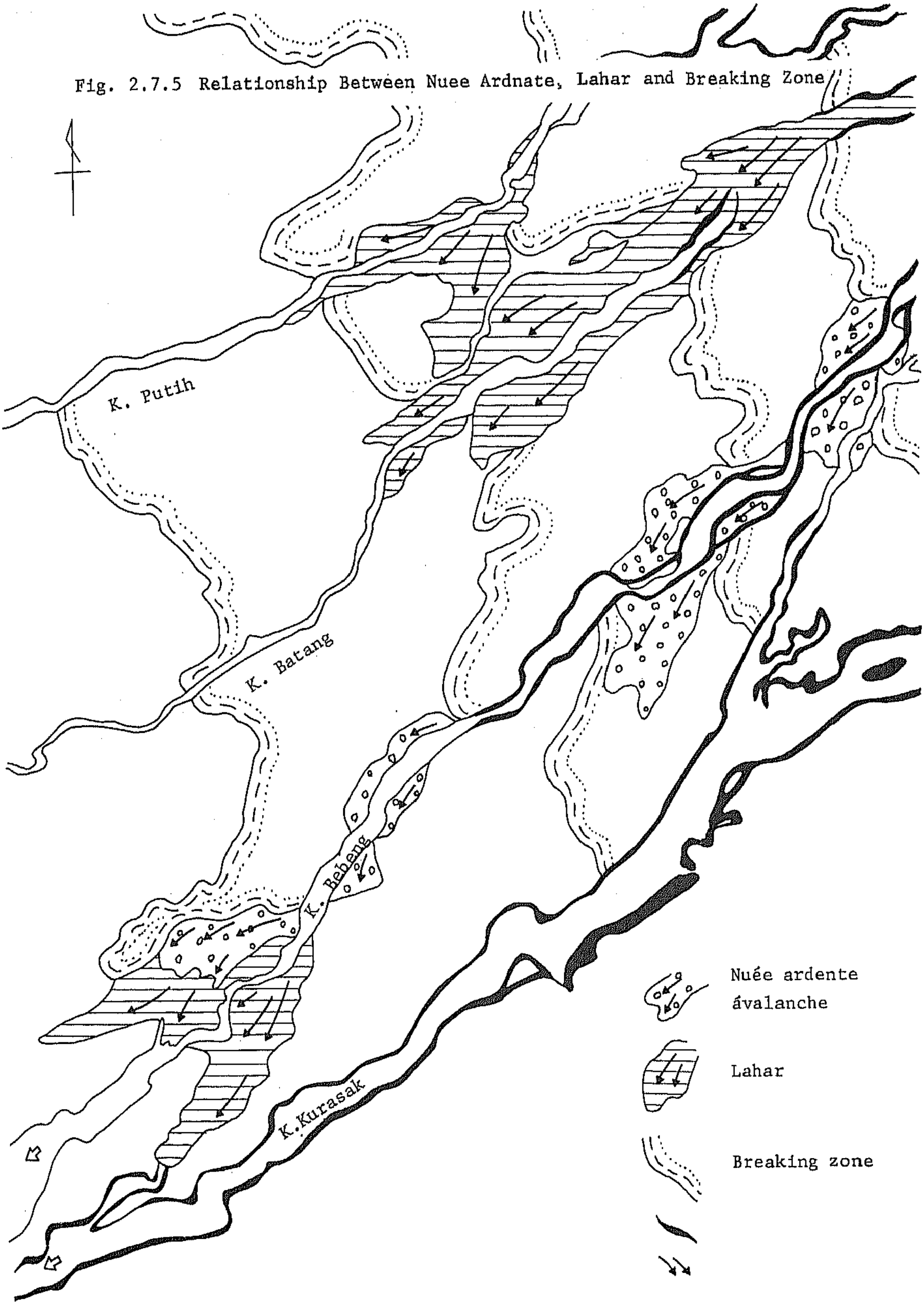
Degrees of Flooding Hazard as Based on River Bank Height

Degree of Danger		River Bank Height (m)
5	Extremely hazardous	0 - 5
4	Very hazardous	5 - 10
3	Hazardous	10 - 20
2	Possibility of flooding	20 - 30
1	Very low possibility of flooding	over 30

In addition, these Catagories of Flooding have been determined;

Classification	Kind of Damage
Class - 1	Damage mainly from sediment
Class - 2	Damage mainly from brief flooding
Class - 3	Damage mainly from long flooding

Fig. 2.7.5 Relationship Between Nuee Ardnate, Lahar and Breaking Zone



2.8 Amounts of Sediment Product and Discharge

2.8.1 Type-I Areas

Figures for the balance of sediment product and discharge in Type-I area for the periods 1969-76, 1969-76, 1969-70, and 1976-77 are given in Tables 2.8.1∿2 and Figs. 2.8.1∿4.

(1) The amount of Sediment Product and Discharge from 1969 to 1976.

a) K. Krasak

During the eight years after the eruption in 1969, the sediment amount of 22,517,000m^3 was producted by erosion and discharged. However it is estimated that 56% (12,679,000m^3 of the sediment discharge was deposited in the channel and the rest 44% (9,838,000m^3) flowed into K. Progo (see Table 2.8.1) The sediment balance is showed in Fig. 2.8.1.

The areas of eroding and depositing along K. Krasak and divided as follows: (See Fig. 2.8.5)

Eroding area:	The area from the crater to 12km
Depositing area:	The channel from 12km to the river mouth

b) K. Putih

The sediment balance on K. Patih is summerized as follows:

Sediment produced:	7,517,000m^3
Sediment deposited:	5,610,000m^3
Discharge amount of: K. Progo	1,907,000m^3

And the eroding area is upper stream between 12km point and the crater (see Table 2.8.2)

(2) Sediment Product and Discharge During the Period from 1969 to 1970

a) K. Krasak

The amount of sediment discharge of Lahar in 1969 at K. Krasak and K. Bebeng is estimated by the longitudinal profiles of the down stream of K. Krasak surveyed immediately after the occurrence of Lahar and the field survey performed by the team. The results are as follows:

(i) According to the questionnaire, the most part of Lahar deposits existing along the upper and middle stream were overflowed in 1969. However at the down stream from the river mouth of K. Bebeng, the Lahar filled the channel but did not overflow.

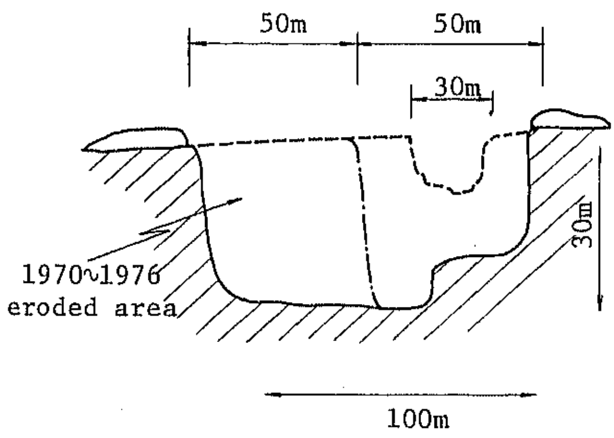
(ii) The amount of sediment at the sandpocket of K. Krasak were remarkably, increased due to the sediments derived by eroding the Lahar deposits of 1969 upper stream.

The situations are estimated as follows:

[K. Bebeng]

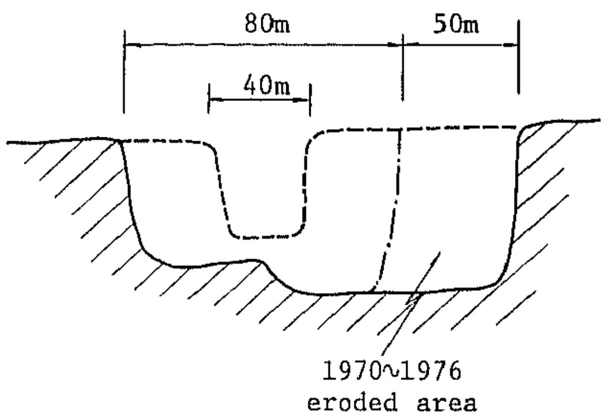
Typical profile of cross sectional area

From 3 - 7km



About 40% of recent cross sectional area was eroded by 1969 Lahar

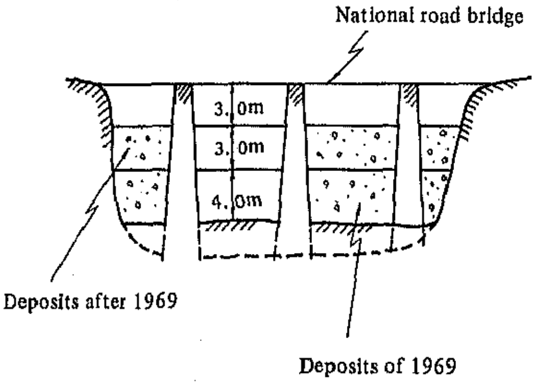
From 7 - 12km



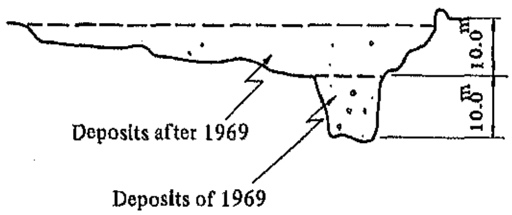
About 60% of recent cross sectional area was eroded by 1969 Lahar

[K. Krasak]

Typical profile of cross sectional area



Typical profile of cross sectional area



The amounts of sediment product and discharge are estimated as follows:

Sediment product	11,804,000m^3
Deposits	5,425,000m^3
Sediment discharge to K. Progo	6,779,000m^3

(3) Sediment Product and Discharge During 1970 to 1976

a) K. Krasak

The amounts of sediment product and discharge are estimated from the amounts of 1969-1970 and 1969-1976 as follows:

- Sediment products: 1,786,000m^3
- Deposits: 1,210,000m^3
- Sediment discharge to K. Progo: 576,000m^3

(4) Sediment Product and Discharge During 1976 to 1977

The amounts of sediment product and discharge are estimated from the river-bed variation and field survey as follows:

- Sediment product: 1,992,000m^3
- Deposits: 1,864,000m^3
- Sediment discharge to K. Progo: 128,000m^3 *

The amount of sediment discharge to K. Progo during 1976-1977 was decreased because about 1,180,000m^3 of sediment discharge was deposited during the flood of Nov. 1976 at the right bank of 29km point.

Amounts of Sediment Discharge to K. Progo

(Unit: $10^3 m^3$)

Period	Product (A)	Deposit (B)	Discharge to K. Progo	B/A
1. 1969∿76	22,517	12,679	9,838	0.56
2. "	2,815	1,585	1,230	"
3. 1969∿70	11,804	5,425	6,779	0.46
4. 1970∿76	1,786	1,210	576	0.68
5. 1976∿77	1,992	1,864	128	0.94

2.8.2 Type-II and Type-III Areas

(1) Present Amount of Unstable Materials

Among the kinds of unstable materials presently found in Type-II and Type-III areas are new volcanic ash, debris, talus, and fan-like deposits on the mountainside, terrace deposits and present riverbed deposits. These unstable materials constitute source of future sediment discharge.

Although the banks of the rivers in the middle and upper slope areas consist of unconsolidated and semi-consolidated loose volcanic ash strata and gravel strata, these materials are not considered to be unstable materials for present purposes.

The method of calculation used was to interpret the surface distribution of various kinds of deposits on the basis of aerial photographs and then to check the thickness of these deposits in subsequent field surveys. The depth of present river-bed deposits has been estimated as 2m, the average change in the level of river-beds as measured in Type-I areas, are presented in Table 2.8.4.

(2) Amount of Possible Sediment Discharge

Except for K. Krasak, it is estimated that the amount of sediment discharge for tributaries in Type-II and Type-III areas is several thousand or tens of thousands of cubic meters a year: i.e, similar to the amount from tributaries in Type-I areas. In the case of K. Woro and K. Gendol, however, there were major occurrence of lahar and banjir flows around 1930 and 1969, causing the formation of terraces in the upper slope area and major scaled overflow and sedimentation in the middle and lower slope areas. Accordingly, it is necessary first to calculate the possible amount of sediment discharge (sediment product) in terms of large-scale flooding for the purposes of disaster prevention planning. Next, it will be necessary to calculate that part of the existing unstable deposit that can be expected to flow out at the time of major flooding. The amount of each tributaries is presented in Table 2.8.5.

Table 2.8.1 Type-I Sediment Balance of K. Krasak and K. Bebong (year 1969 ∿ 1976)

Distance from the summit (Km)	Overflowed deposit D1	Deposit in channel D2	Total deposit Dt=D1+D2	Maximum volume of deposit E1	Volume of former channel E2	Total volume of erosion Et=E1–E2	Accumulated sediment discharge V=Σ(Et–Dt)
* 0 ∿ 7	(1,100) 1,359	-	1,359	(9,660) 11,930	-	11,930	10,571
∿ 8	(18) 22	166	188	(3,020) 3,730	(150) 185	3,545	13,927
∿ 9	(94) 116	151	267	(1,919) 2,370	(150) 185	2,185	15,846
∿10	(207) 256	176	432	(2,693) 3,326	(200) 247	3,079	18,493
∿11	(26) 32	80	112	(1,502) 1,855	(300) 371	1,484	19,865
∿12	(74) 91		91	(396) 489	(300) 371	118	19,892
∿13	(1,066) 1,317		1,317				18,575
K. Krasak confluence point ∿15		921	921			176	17,830
National road ∿17.6		1,574	1,574				16,256
∿20		1,392	1,392				14,864
∿24		4,575	4,575				10,289
K. Progo confluence point ∿27		451	451				9,838
Total	(2,585) 3,193	9,486	12,679	(19,130) 23,700	1,359	22,341	9,838

Figure in ( ) means volume before to be loosened.

* • Items of volume in the section between $0^{km} \sim 7^{km}$ (in volume before to be loosened).

- Volume of Sediment product from area ($334{,}000 m^2$) x mean depth (3m)
- The Upper - most area (0 ~ 3km) : $E_{1\text{-}1} = 1{,}000 \times 10^3 m^3$
- Volume of Sediment products derived from gully erosion (3 ~7km):

  $E_{1\text{-}2} = 8{,}660 \times 10^3 m^3$ (after field survey)
- Total volume of erosion:

  $E_t = E_1 = 9{,}660 \times 10^3 m$
- Volume of fan-like deposits between 3 ~ 7km

  $D_1 = D_t = 1{,}100 \times 10^3 m$ (after field survey and photo interpretation)

Table 2.8.2 Type-I Sediment Balance of K. Putih (year 1969 ∿ 1976)

Distance from the summit (Km)	Overflowed deposit D1	Deposit in channel D2	Total deposit Dt=D1+D2	Maximum volume of deposit E1	Volume of former channel E2	Total volume of erosion Et=E1−E2	Accumulated sediment discharge V=Σ(Et−Dt)
* 0 ∿ 5	(2,008) 2,480	–	2,480	(3,222) 3,979		3,979	1,499
∿ 6	(176) 217	93	310	(2,341) 2,891	(1,124) 1,388	1,503	2,692
∿ 7	(260) 321	66	387	(2,381) 2,941	(1,157) 1,429	1,512	3,817
Juranjero ∿ 8	0	402	402	(678) 837	(339) 419	418	3,833
∿ 9	(13) 16	85	101	(1,121) 1,384	(1,036) 1,279	105	3,837
∿10	(120) 148	40	188	(271) 335	(271) 335	0	3,649
∿11	(43) 53	40	93	(243) 300	(243) 300	0	3,556
∿12	(101) 125	100	225				3,331
∿13	(81) 100	90	190				3,141
∿14	(78) 96	60	156				2,985
∿15	(63) 78	80	158				2,827
∿16	(75) 93	60	153				2,674
∿17	(29) 36	50	86				2,588
National road ∿18	(130) 161	20	181				2,407
K. Progo confluence point ∿23		500	500				1,907
Total	(3,177) 3,924	1,686	5,610	(10,257) 12,667	(4,169) 5,150	7,517	1,907

* • Items of volume in the section between 0 ~ 5km (in volume before to be loosed)

- Volume of sediment product from the upper-most area (0 ~ 3km)

  $670{,}000 m^2 \times 3 m = 2{,}010 \times 10^3 m^3$

- Volume of sediment products derived from gully-erosion = $1{,}212 \times 10^3 m^3$
- Total volume of erosion = $3{,}322 \times 10^3 m^3$
- Volume of fan-like deposits = $2{,}008 \times 10^3 m^3$

Fig. 2.8.1 The Balance of Sediment Product and Discharge Along K. Krasak (from Jan. '69 to Oct. '76)

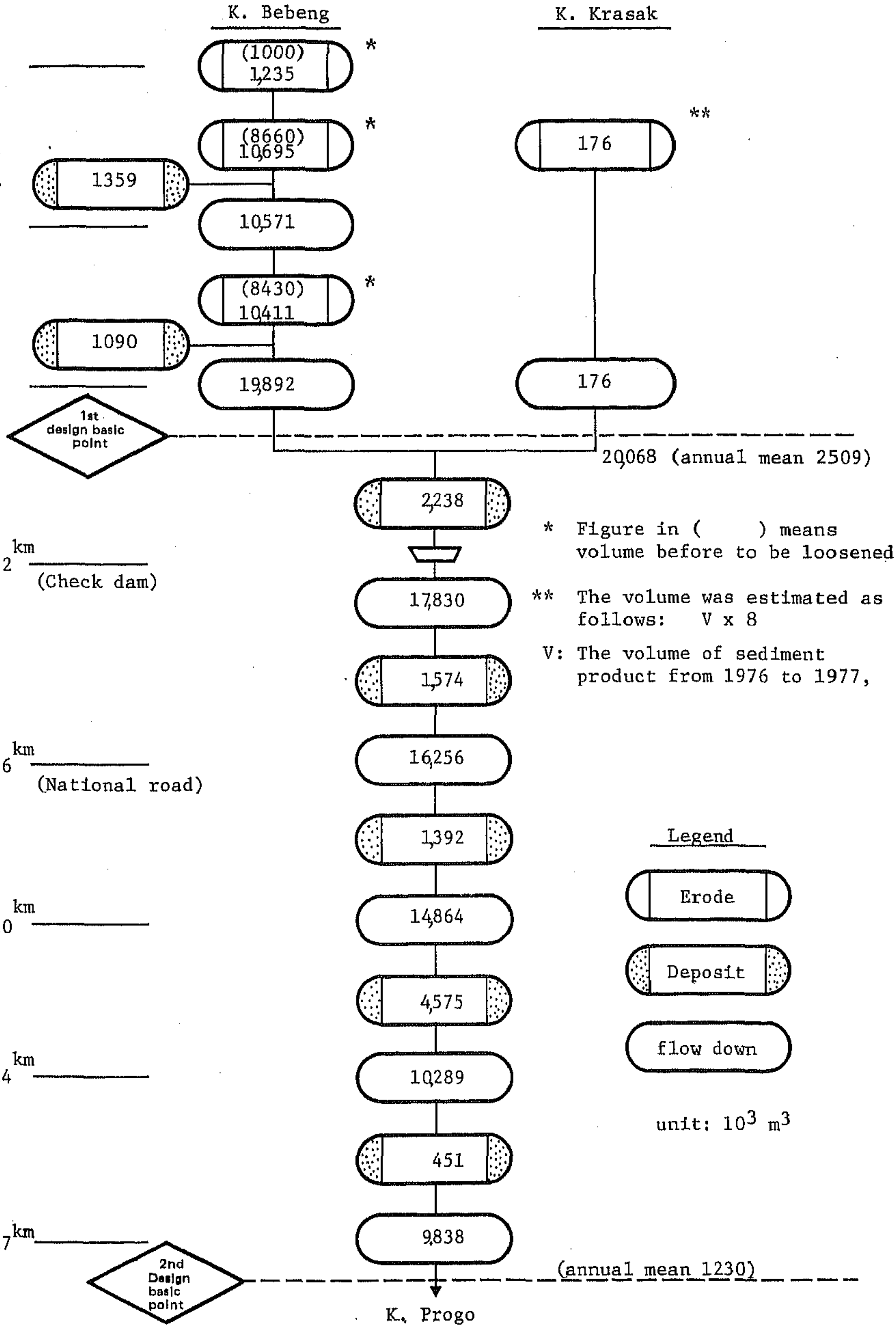


Fig. 2.8.2 The Balance of Sediment Product and Discharge Along K. Krasak (from Jan. '69 to Oct. '76)

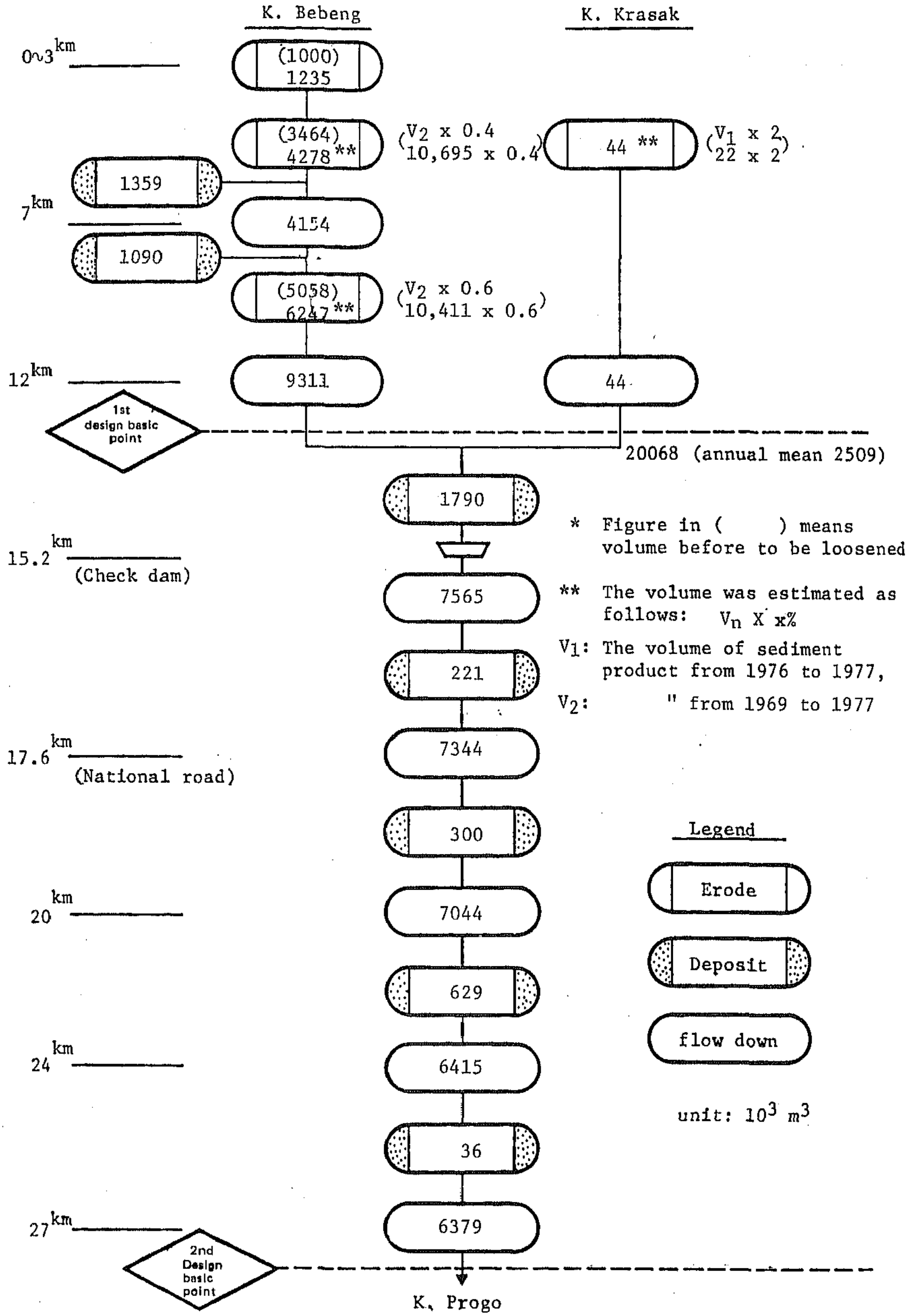


Fig. 2.8.3 The Balance of Sediment Product and Discharge Along K. Krasak (from Nov. '76 to Oct. '77)

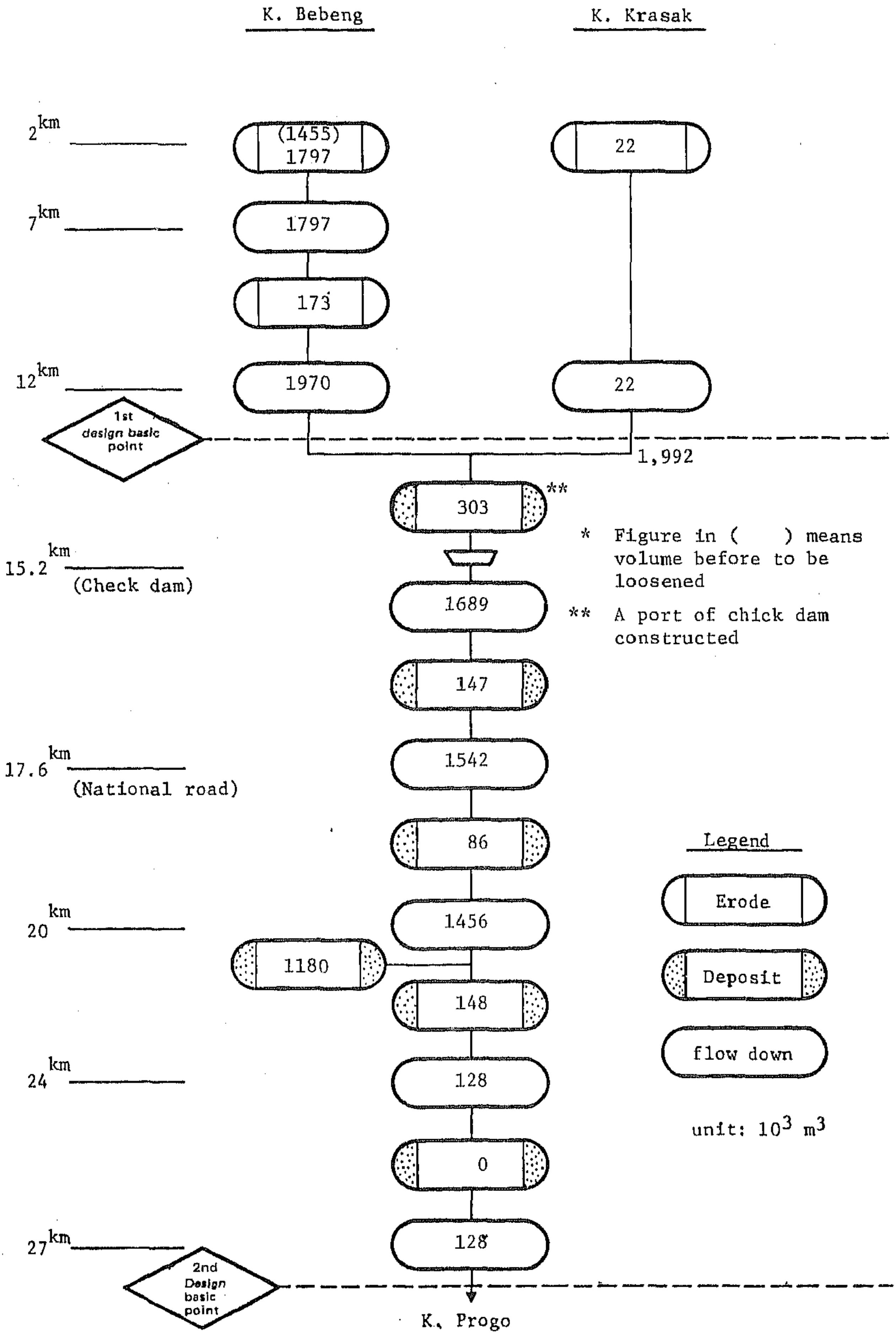
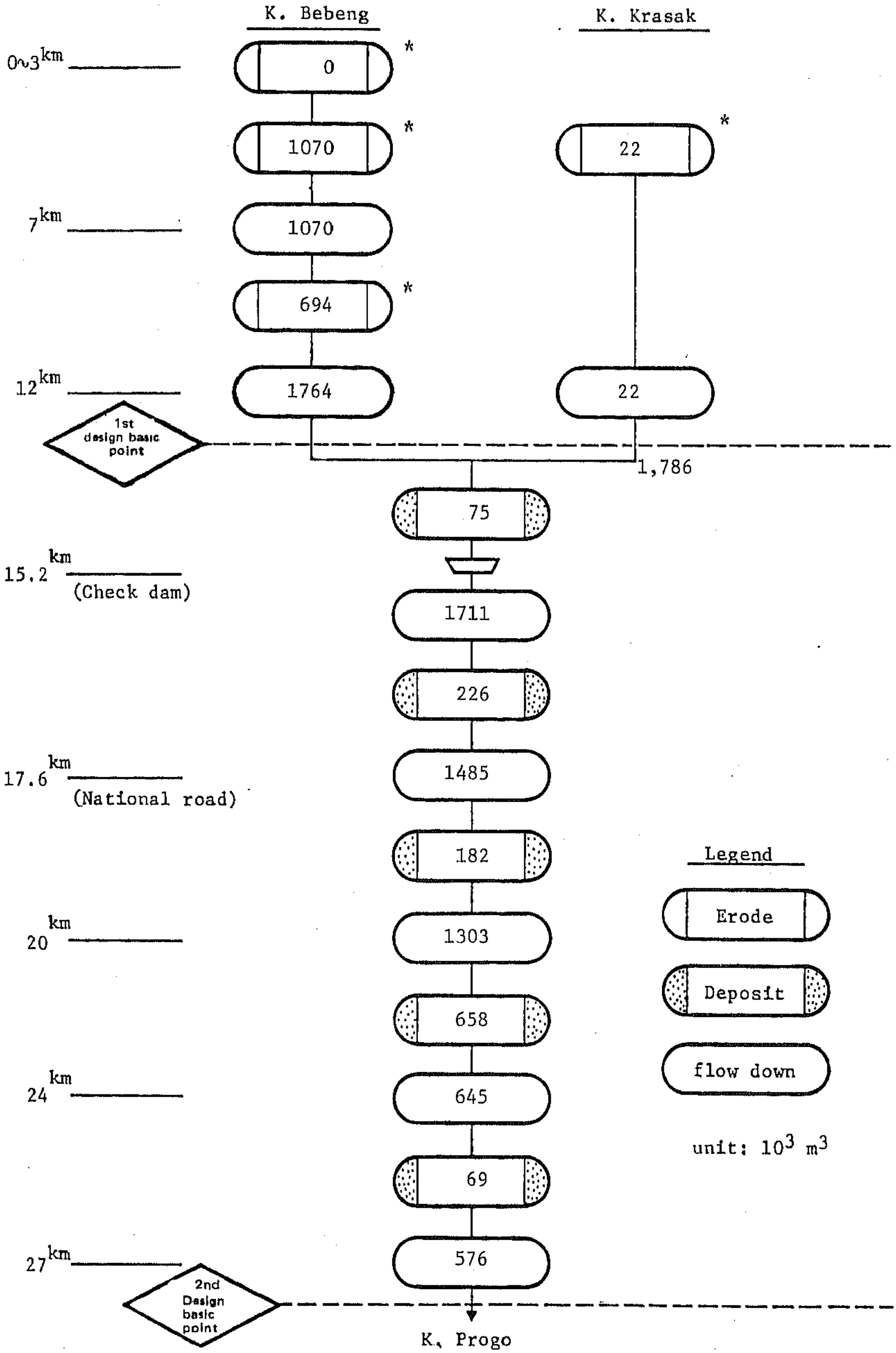


Fig. 2.8.4 The Balance of Sediment Product and Discharge Along K. Krasak (from Jan. '69 to Oct. '76)



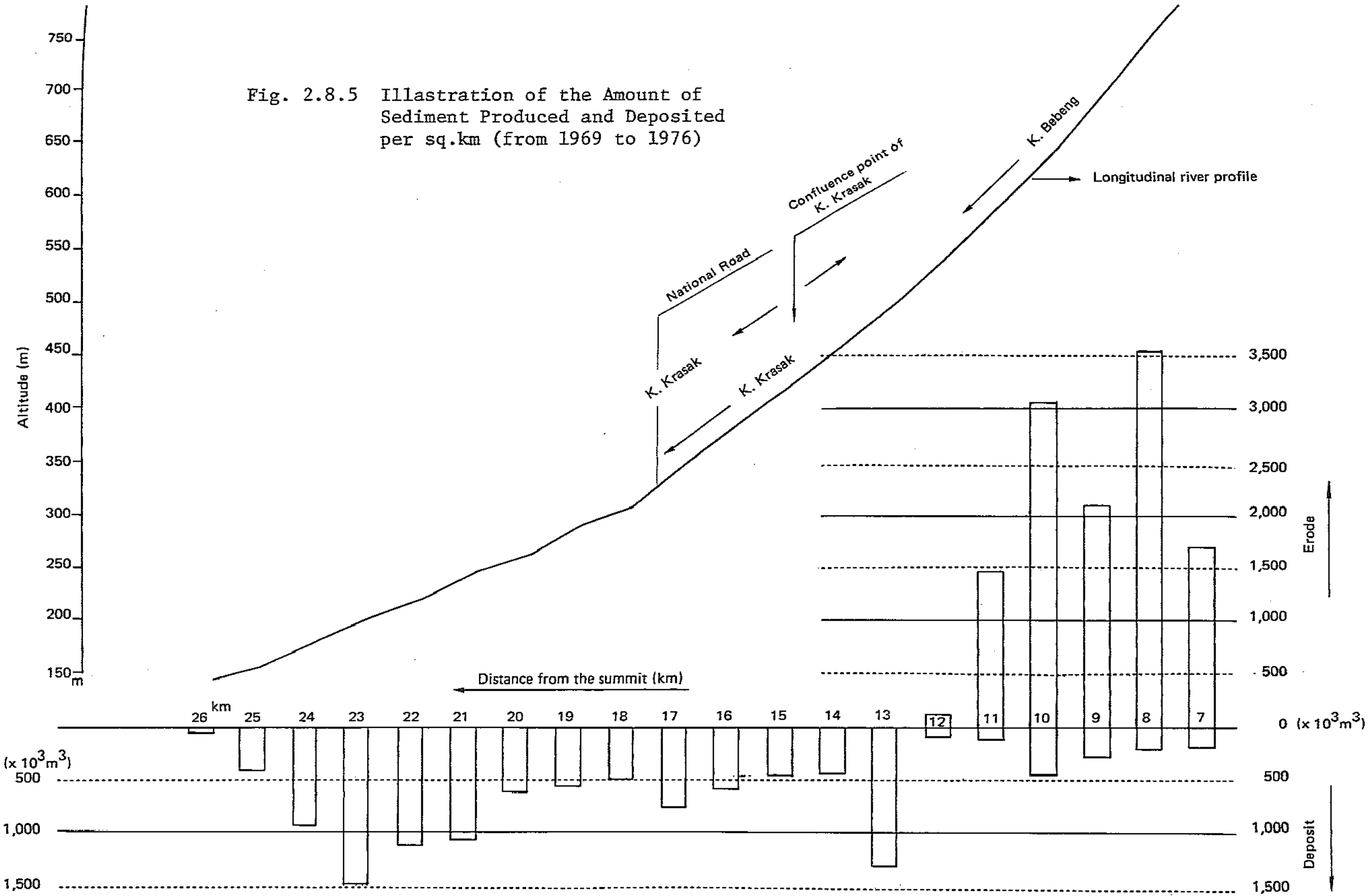


Fig. 2.8.5 Illastration of the Amount of Sediment Produced and Deposited per sq.km (from 1969 to 1976)

Table 2.8.3 Outline of Calculation of Riverbed Variation by Aerial Photography, 1976 - 1977 year

annotation: A. Nakasuji owns more detailed backdater

Interval of survey line	K. Krasak		K. Bebeng	K. Bebeng	K. Batang	K. Batang	K. Putih		K. Blongkeng	
	Section change volume	Accumulation change volume	Section	Accumulation	Section	Accumulation	Section	Accumulation	Section	Accumulation
5km	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)
~ 6	-11,300	-11,300	2,600	2,600						
~ 7	-10,700	-22,000	-19,900	-17,300						
~ 8	-8,300	-30,300	-12,700	-30,000	-3,000	-3,000	4,700	4,700	-1,300	-1,300
~ 9	2,300	-28,000	8,900	-21,100	-1,100	-4,100	-11,400	-6,700	0	-1,300
~ 10	-200	-28,200	-28,600	-49,700	1,800	-2,300	4,300	-2,400	8,600	7,300
~ 11	5,000	-23,200	-106,100	-155,800	2,500	200	300	-2,100	-20,300	-13,000
~ 12	1,400	-21,800	-34,700	-190,500	-1,500	-5,300	-11,400	-13,500	-14,000	-27,000
~ 13	2,800	-19,000	14,100	-176,400	-3,200	-4,500	6,600	-6,900	7,300	-19,700
~ 14	5,600	-13,400	69,800	-106,600	-9,200	-15,700	5,800	-1,100	6,100	-13,600
~ 15	-24,300	-37,700	158,500	51,900	-2,700	-16,400	2,200	1,100	8,600	-5,000
~ 16	125,700	139,900			-2,400	-18,800	-6,000	-4,900	-3,300	-8,300
~ 17	47,800	187,700			-5,900	-24,700	-11,500	-16,400	1,200	-7,100
~ 18	54,100	241,800			-14,600	-39,300	3,300	-13,100	-1,500	-8,600
~ 19	38,500	280,300			-4,400	-43,200	-1,800	-14,900	-12,800	-21,400
~ 20	43,600	323,900			-10,400	-54,100	11,700	-3,200	-9,100	-30,500
~ 21	103,600	427,500			-4,700	-58,800	-4,300	-7,500	-7,000	-37,500
~ 21.5	44,000	471,500								
~ 22					-3,800	-62,600	-800	-8,300	-6,700	-44,200
~ 23					-900	-63,500	3,000	-5,300	-2,400	-46,600
~ 24									-5,400	-52,000
~ 25										

- = erosion, + = deposition

Table 2.8.4 Present Unstable Deposits in Type II and Type III

Name of river	Distance from the summit (km)	Recent riverbed deposits (x 10³m³)	Lower Terrace deposits (x 10³m³)	Middle and higher terrace deposits (x 10³m³)	Other unstable deposits (x 10³m³)	Total volume (x 10³m³)
K. Woro	0 ~ 12	1,198	(343) 424	(1,875) 2,316	(1,900) 2,347	6,285
Sandpocket of K. Woro	12 ~ 17	1,375	4,500	-	-	5,875
K. Gendol	0 ~ 19	874	(1,468) 1,813	(837) 1,034	(2,125) 2,624	6,345
K. Kuning	0 ~ 18	830	(1,183) 1,461	(238) 294	(648) 800	3,385
K. Boyong	0 ~ 17	755	(519) 641	(484) 598	(128) 158	2,152
K. Senowo	0 ~ 12	610	(324) 399	(685) 846	(366) 452	2,307
K. Trising	0 ~ 19	1,112	(1,817) 2,243	(212) 262	(186) 230	3,847

( ) means volume before to be loosend bulk factor of soil = 1.235

Table 2.8.5 Possible Sediment Discharge Volume in Type II and Type III

Name of river	Area of basin (km²)	Distance from the summit (km)	Recent riverbed deposits (x 10³m³)	Lower terrace deposits (x 10³m³)	Middle and higher terrace deposits (x 10³m³)	Other unstable deposits (x 10³m³)	Volume of sediment products (x 10³m³)	Specific probable volume (x 10³m³/km2
K. Woro	7.1	0~10	637	(343) 424	(1,500) 1,853	(1,057) 1,305	4 4,219	594
K. Gendol	10.5	~13	400	(390) 482	(670) 827	(1,173) 1,449	3,158	301
K. Kuning	9.6	~13	320	(720) 889	(190) 235	(324) 400	1,844	192
K. Boyong	10.3	~13	445	(349) 431	(332) 410	(114) 141	1,437	140
K. Senowo	8.8	~12	510	(323) 399	(548) 677	(223) 275	1,861	211
K. Trising	12.4	~12	400	(483) 597	(170) 210	(123) 152	1,359	110

( ) means volume of before to be loosend bulk factor of soil = 1.235

PART 3 PRELIMINARY DISASTER PREUENTION PLAN

PART 3 PRELIMINARY DISASTER PREVENTION PLAN

3.1 Goals of the Plan

1) Tasks in the Area

The Yogyakarta has always been influenced by G. Merapi in terms of both enjoying superb seenic vistors and suffering repeated damage from eruptions and flows of volcanic materials. As more infrastructure such as irrigation works roads, railroads, and other important facilities has been provided, they have also suffered pronounced damage.

In 1969, the Indonesian Government set up a Merapi Project Office in Yogyakarta to cope with emergencies and construct disaster prevention works. Since G. Merapi exerts such a wide spectrum of influences over all aspects of community and economic life, programs to increase safety and stability in the area must be approached from a broad perspective.

Surveys, made of existing conditions in the area in both 1977 and 1978 spotlight the following tasks facing the area:

a) Need to reduce the danger to people living in the area and property damage caused by eruptions and flow of volcanic materials from G. Merapi.

b) Need to reduce damage and instability in the area caused by river sediment discharge by controlling and adjusting the flow of rivers.

c) Need to stabilize and improve the production and living conditions of the area in coordination with national programs.

The goals of the disaster prevention plan can therefore be summarized as those of protecting the lives and property of residents and of increasing the stability of the area's production and living conditions by controlling and stabilizing the river.

2) Project Period

Considering the historical disaster cycle, it will be necessary to complete the project within fifteen to twenty years. This will involve the setting of priorities with respect to the probable danger and importance of different zones in the project area and the formulation of comprehensive short, medium, and long-term implementation plans.

3) Area to be Covered by the Plan

The plan will focus on the following types of areas in order to effectively implement the project goals and maximize the effect of the major measures to be taken:

a) Regional Disaster Prevention Area

An area approx. 900km^2 on the slopes of G. Merapi.

b) Trouble Spot Countermeasure Area

Trouble spots located along K. Opak and K. Progo.

4) Goals

a) Regional Disaster Prevention Plan

On the slopes of G. Merapi, some 440,000 residents are exposed to danger from the volcanic activity of G. Merapi, and about of the land is subject to damage. There are large amounts of loose material deposited at headwaters in the area, and the possibility of lahar and other damage is rather big. There is always the danger of a new eruption. Accordingly, the present plan proposes to make the lives of residents safer through resettlement and warning systems that reduce damage to land and property by reducing the hazard zone, and through disaster prevention works control the amount of sediment carried downstream, thereby laying a foundation for stabilization and improvement of production and living conditions in the area.

b) Trouble Spot Countermeasure Plan

The primary trouble spots along K. Progo and K. Opak are the following: Sedimentation to irrigation intakes and internal drainage system, closing river mouth by driftsand, river bank erosion etc. The following sections outline basic countermeasures for coping with trouble spots.

3.2 Regional Disaster Prevention Plan

3.2.1 Area Classification and Countermeasures

1) Area Classification

Natural and socieconomic conditions vary within the project area, which covers approximately 900km^2. There is also variation in the degree of danger in terms of topographical and geological conditions, the amount of social and economic infrastructure, and hence in productivity and living conditions.

In order to be able to increase the safety of residents and stabilize production and living conditions more effectively by means of the disaster prevention works, the disaster prevention plan provides for special countermeasures for each different zone, in terms of its specific degree of danger and importance.

The following Table 3.2.1 summarizes the basic factors used to rank, the degree of danger and importance of each sector of the area being considered.

As a result, the area has divided into the following four zones:

Zone - 1	Where the inhabitant should be protected only by the relocalion outside the zone.
Zone - 2	Where the inhabitant should be protected by a warning system.
Zone - 3	Where the inhabitant and property should be protected by sabo works.
Zone - 4	Where the possibilities of damage from the lahar or banjir is very small.

Table 3.2.1 Summary of Factors Considered

Natural	Social and Economic
Estimated flooding areas	Population
Damage frequency (by type of river)	Land use pattern
Hazard map (extent of nuee ardent)	Distribution of social infra-structure (roads, main irriga-tion channels, etc.)
Damage categories (lahar and banjir)	Irrigation categories (technical, semi-technical, and non-technical)
	Land productivity

i) Degree of danger and importance

The overall method for determining degree of danger and importance of specific sectors in the area is summerized in the following four steps and then explained in detail in the following paragraphs:

(1) Classification of five categories of the basic volcanic and socio-economic information in terms of degrees of danger or importance.

(2) Arrangement of the classified information on a grid with mesh representing a surveyed area 500m by 500m.

(3) Determination of multipile degrees of danger or importance for zones with over lapping grid areas.

(4) Determination of area divisions for the disaster prevention plan based on zones of danger and importance.

a) Degree of danger

The degree of danger is expressed as a combination of factors (listed below), since the actual danger depends greatly on the direction of the volcanic eruption, the amount of volcanic material emitted, and topographical conditions:

(1) Possible danger influenced by topographical or geomorphological conditions ....

- Degree of possibility of dangerous flooding. (Scale of I-V, see section 2.7.3)

(2) Frequency of disasters due to volcanic eruptions or the volcanic material emitted by eruptions ......

- River Types I - III and Other Zones. (Type - IV).

(3) Extent of damage or disasters ....

- The zones reached by nuee ardente, lahar, and banjir, respectively.

b) Degree of importance

Area importance is expressed as a combination of social and economic factors (listed below) since the actual importance depends on the number of inhabitants and amount of property in the particular zone, the productivity of the zone, and the extent of damage sustained.

(1) Social importance

Social inportance is expressed in terms of the amount of direct and indirect damage inflicted and the difficulty of restoration to its original state ....

- Population density.
- Distribution of community infrastructure and other important facilities.
- Distribution of urbanized areas and villages (land use).

(2) Economic Importance

Economic importance is expressed in terms of present productivity and agricultural growth potential, most critical productive sector in this area, and other sectors ......

- Distribution of paddy field (land use).
- Crop yield indices (1976/1971).

- Present level of paddy yield.
- Potential paddy yield. (1981)

ii) Expression of Degree of Danger and Importance

a) Grid Square System

The grid square system has been used for evaluation of degree of danger and importance in the area for the following reasons:

(1) In making a comparative study of different areas, it is necessary to disregard administrative boundaries and to standardize zone size. The grid system offers the advantages of dividing the area into geometrically equal shapes and displaying data visually.

(2) Since the area of each mesh in a grid system is the same, the mesh area functions as a common demonstrator for making area comparisons.

(3) Since a grid system is not influenced by variation in administrative area, topography, land use, etc., historical comparisons are facilitated.

(4) Since each area has the same shape, grids more easily show the relationship between location and shape of area phenomena.

(5) Information from standard surveys can make up for gaps in existing information for a particular zone since the grid areas are divided into equal parts.

(6) A broad statistical approach can be taken using accurate high-speed electronic computers.

(7) Since data on terrain, land use, and other conditions will be expressed in terms of mesh squares measuring 0.5km on a side, the system of coordinates can easily be converted to coordinates of longitude and latitude.

b) Basic Data

Evaluation of present conditions is based on the following sources of information:

Type of Information	Statistical Source
(1) Population	Population density data (1976)
(2) Land productivity	Crop yield indices data (1971)
	" (1976)
	Yield of paddy data (1976)
	Projection of paddy yield data (1981)
(3) Land use	Social division (land use map)
	Economic division land use map)
	Form of irrigation map
(4) Social infrastructure and other important facilities	Roads, irrigation facilities, etc.
(5) Topographical conditions	Slope grade map
(6) Volcanic damage	Type of volcanic material (nuee ardente, lahar, and banjir area map).
	Volcano frequency (direction of eruption and river types map).
	Degree of possible flooding map.

iii) Statistical Summary

(1)	Population density division (1976)	Fig. 3.2.1
(2)	Crop yield division	Fig. 3.2.2
(3)	Yield of paddy division (1976)	Fig. 3.2.3
(4)	Present tendency of yield of paddy division (1981)	Fig. 3.2.4
(5)	Social land use division	Fig. 3.2.5
(6)	Economic land use division	Fig. 3.2.6
(7)	Irrigation areas division	Fig. 3.2.7

(8) Possible hazard area division — Fig. 3.2.8

(9) Slope grades division — Fig. 3.2.9

iv) Statistics of Degree of Danger and Importance

(10) Possible hazard area division (Fig. 3.2.10)

a. [1] Possible hazard area division (Fig. 3.2.8) → (10)

b. [2] Damage divisions: nuee ardente, lahar and banjir → (10)

c. [3] Damage frequency → (10)

$$\log(10) = \frac{1}{3}\left(\log(a) + \log(b) + \log(c)\right)$$

(11) Degree of social importance classification (Fig. 3.2.11)

d. Population density division (1976) → (11)

e. Social land use division → (11)

f. Distribution of social infrastructure and other important facilities. → (11)

$$\log(11) = \frac{1}{3}\left(\log(d) + \log(e) + \log(f)\right)$$

(12) Degree of economic importance classification (Fig. 3.2.12)

g. Crop yield index division ┐

h. Paddy productivity division ┘ → (12)

i. Economic land use division → (12)

$$\log(12) = \frac{1}{2}\{(\frac{1}{2}(\log(g) + \log(h) + \log(i)\}$$

(13) Degree of future economic importance classification (Fig. 3.2.13)

j. Crop yield index division ┐

k. Future productivity of yield of paddy division ┘ → (13)

l. Economic land use division → (13)

$$\log(13) = \frac{1}{2}\{(\frac{1}{2}(\log(j) + \log(k) + \log(l)\}$$

Notes: 1) Present tendency of paddy yield division (1981)

The estimated yield of paddy in 1981 are obtained from the following equation:

$$\bar{Y} = a + bt + u$$

where Y: Estimated yield (q/ha)

a: The present level of paddy yield in 1976 (q/ha)

b: The increasing or decreasing tendency (q/ha/year)

t: time Period (year).. 5

u: Error term .... Estimated as "0"

2) Damage divisions: nuee ardente, zone, lahar zone and Banjir zone. Divisions and values determined for each zone are as follows:

. Nuee Ardente Zone 5

. Lahar Zone 4

. Banjir Zone 3

. Others 1

3) Damage frequency

The hazard areas have been divided into four types divisions and values determined as follows:

. Type - I area 5

. Type - II area 3

. Type - III area 2

. Type - IV* area 1

* Type - IV area indicates land outside the proposed hazard area.

v) Zoning Areas and their Countermeasures

The study area is zoned to the following form zone on the basis of danger and importance degree classifications as follows:

(The hazard area from nuée ardente)

Zone - 1 { Type - I

Zone - 2 { Type - II, Type - III

Zone - 3 (other areas)

Zonal Range of Degree of Danger and Importance

	Degree of Danger					Degree of Socio-economic importance				
	1	2	3	4	5	1	2	3	4	5
Zone - 1	o					o	o	o	o	o
Zone - 2		o	o	o	o	o	o	o	o	o
Zone - 3			o	o	o			o	o	o

(Zone - 1) Where the inhabitant should be protected only by relocation outside area.

From the stand-point of protecting human life first, habitation in nuée ardente hazard zone of type - I should be prohibited and the present inhabitants should be immediately relocated.

(Zone - 2) The inhabitants should be protected by a warning system.

The inhabitants in the other hazard areas (Possibly nuée ardente hazard area of types-II-III and all lahar/banjir areas of types-I-III) should also be protected by a warning system.

(Zone - 3) The inhabitants and property should be protected by Sabo works.

In order to reduce the damage and stabilizing the channels, the possible lahar/banjir hazard areas should be protected to some extent by sabo works.

(Zone - 4) The hazard possibilities from the lahar/banjir are very small in this area because it lies outside the hazard zone and therefore it should be excluded from the objectives of sabo works at this time.

Fig. 3.2.0 General Location Map of Grid Square System

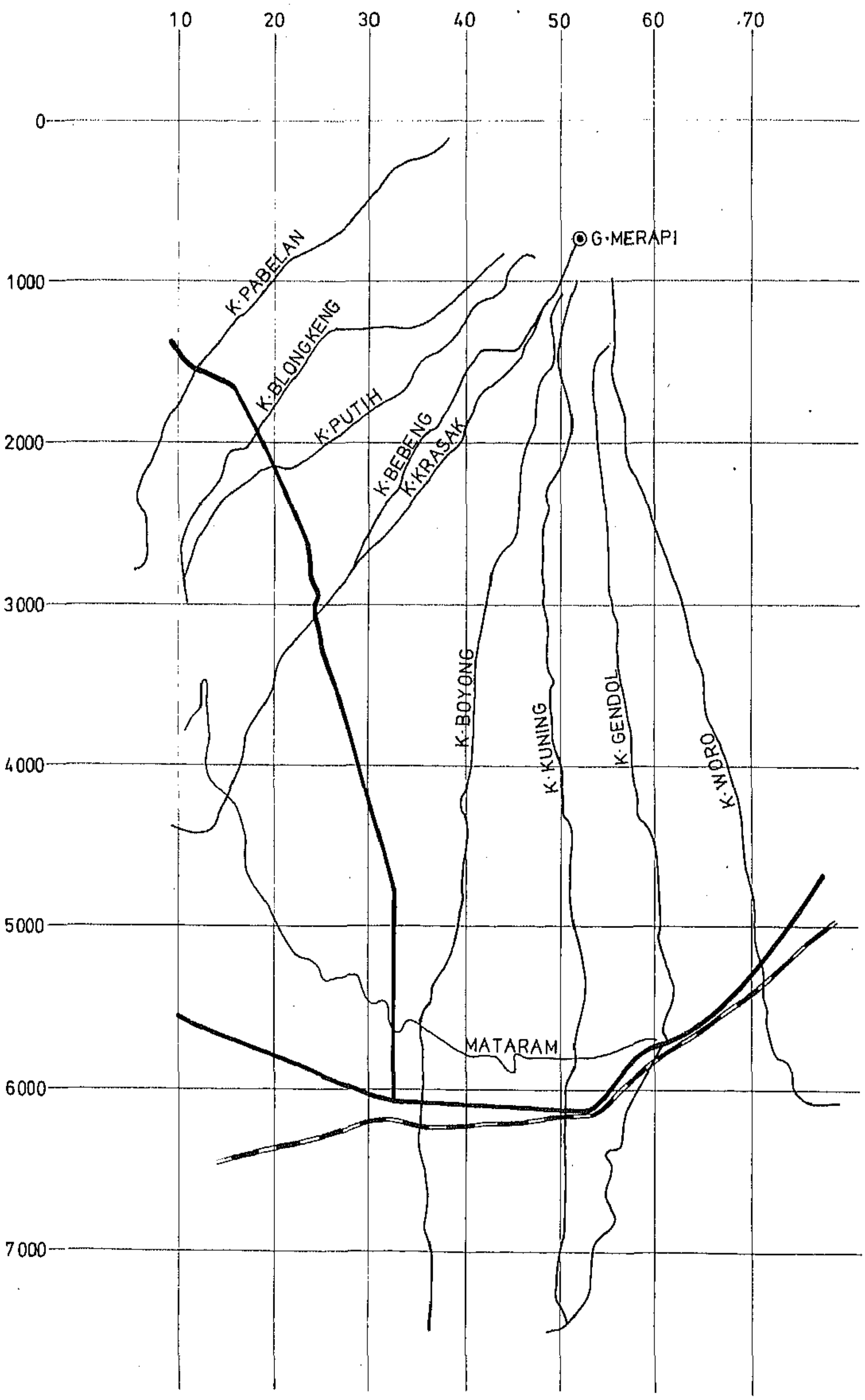


Fig. 3.2.1 Poputation Density Division of 1976

NUMBER

LEVEL	SIGN	NUMBER	Number of		
0	x	581	Pop. density below	500	1 sq. km
1	*	1019	"	in 500 - 1,100	"
2	x	1548	"	in 1,100 - 1,700	"
3	H	383	"	in 1,700 - 2,300	"
4	■	404	"	over 2,300	"
	ERROR	1763			

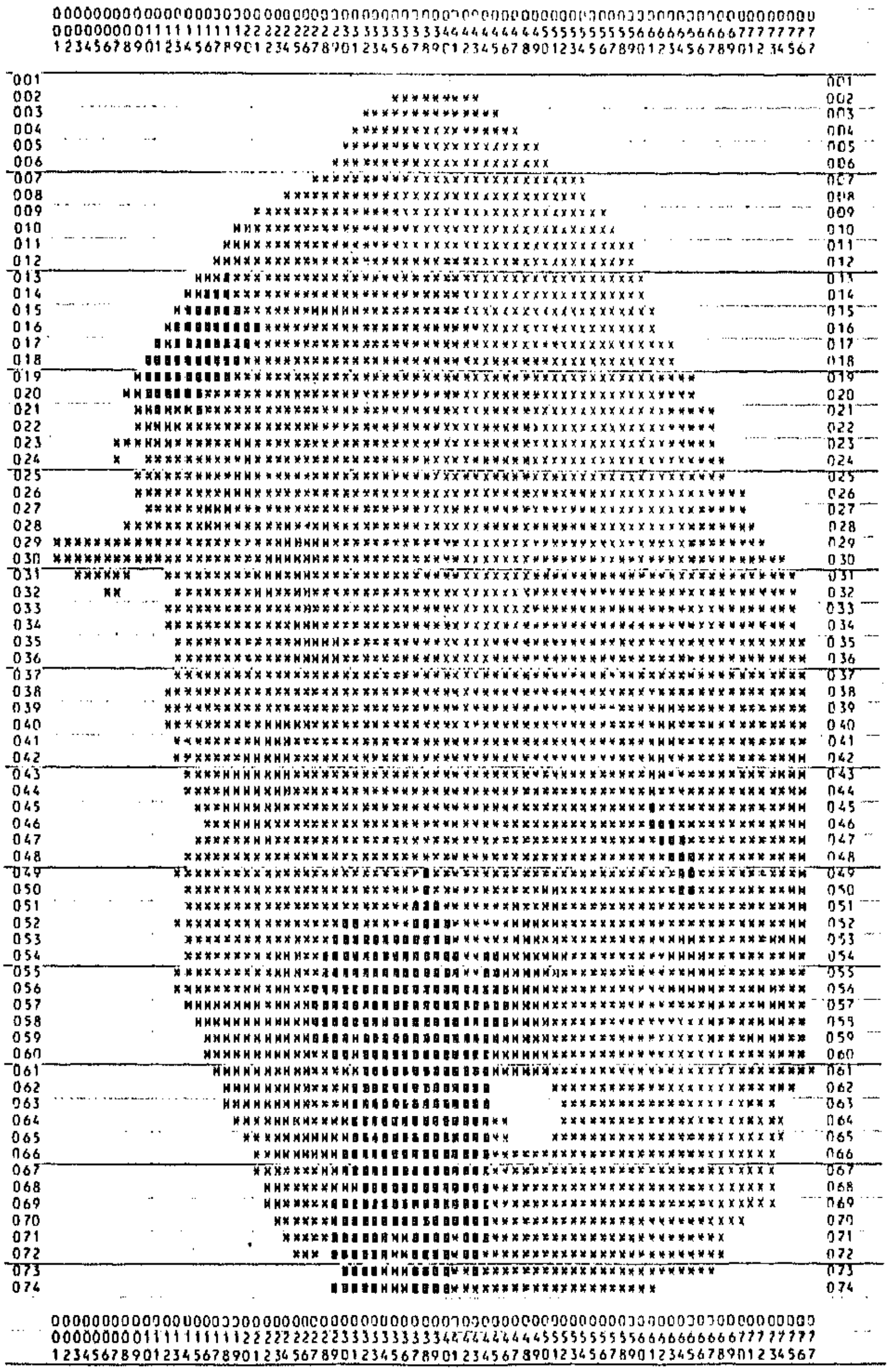


Fig. 3.2.2 Crop Yield Division

LEVEL	SIGN	NUMBER	
0	x	203	Very Low level of land productivity both 1971 and 1976
1	*	844	Low level of land productivity both 1971 and 1976
2	*	327	Land productivity decreasing—more than 100% in 1971 but less than100% in 1976
3	H	1574	Land productivity increasing —less than 100% in 1971 but more than 100% in 1976
4	■	987	High level of land productivity both in 1971 and 1976
ERROR		1763	

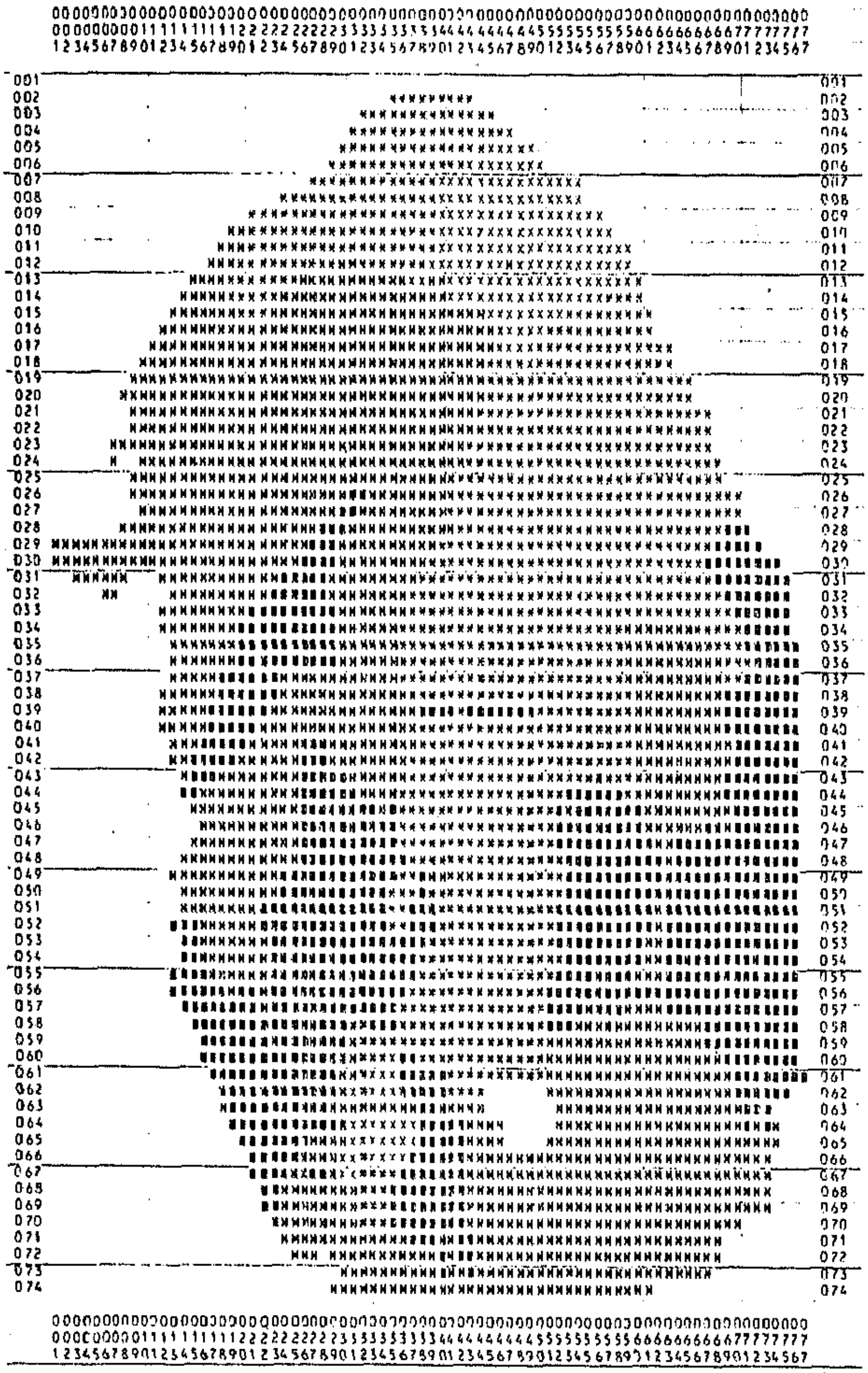


Fig. 3.2.3 Yield of Paddy Division (1976)

NUMBER

LEVEL	SIGN	NUMBER	
0	X	211	below 37.5 q/ha
1	*	1127	In 37.5 – 42.5 q/ha
2	*	1816	In 42.5 – 47.5 q/ha
3	*	373	In 47.5 – 52.5 q/ha
4	▮	406	above 52.5 q/ha
	ERROR	1763	

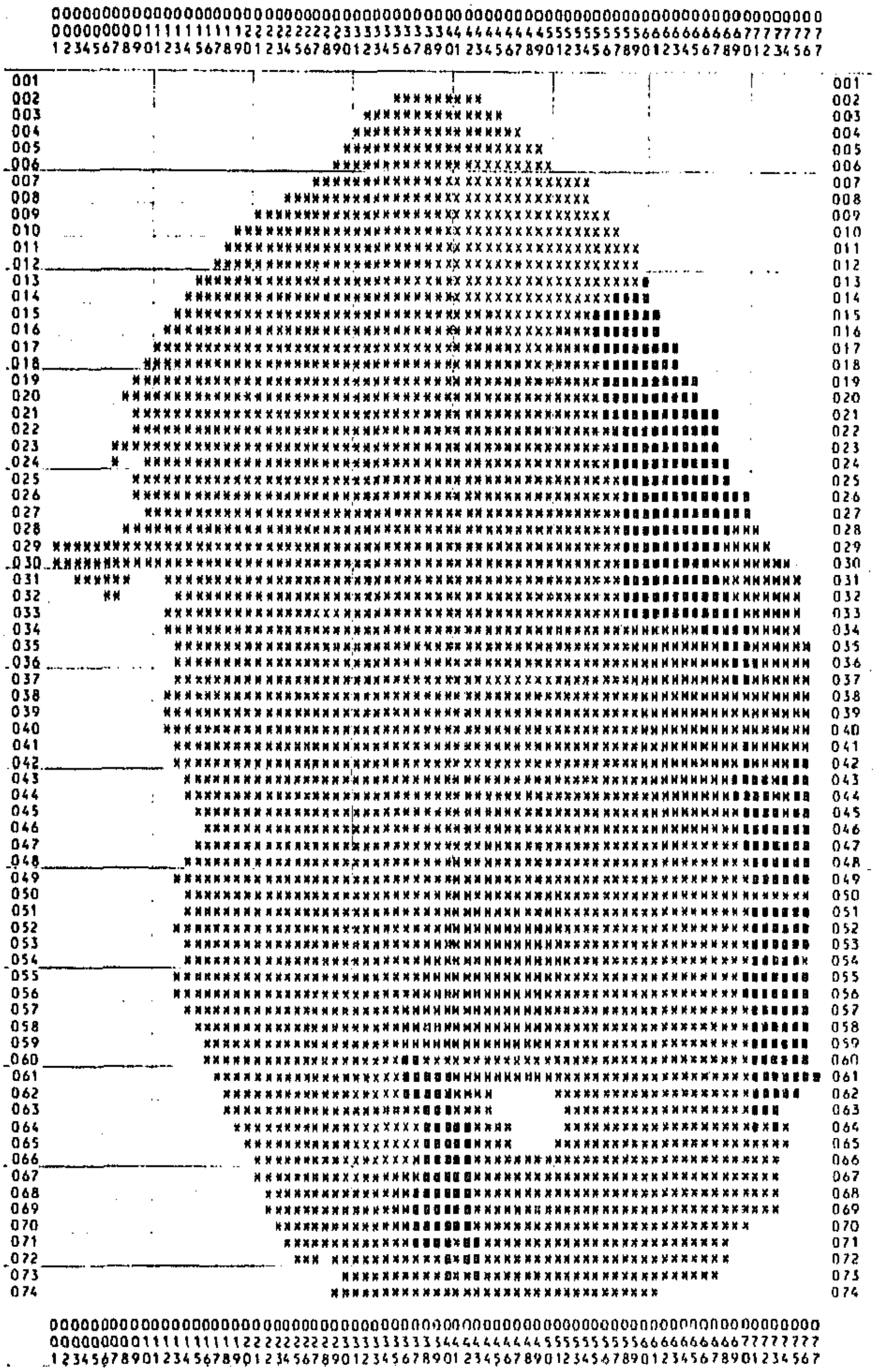


Fig. 3.2.4 Present Tendency of Yield of Paddy Division (1981*)

NUMBER

LEVEL	SIGN	NUMBER		
0	x	346	below 37.5	
1	*	245	in 37.5 – 42.5	q/ha
2	x	1095	in 42.5 – 47.5	q/ha
3	H	1655	in 47.5 – 52.5	q/ha
4	■	594	above 52.5	q/ha
	ERROR	1763		

* Values of the Paddy yield estimated from the equation – Y = a + bt (t = 6)

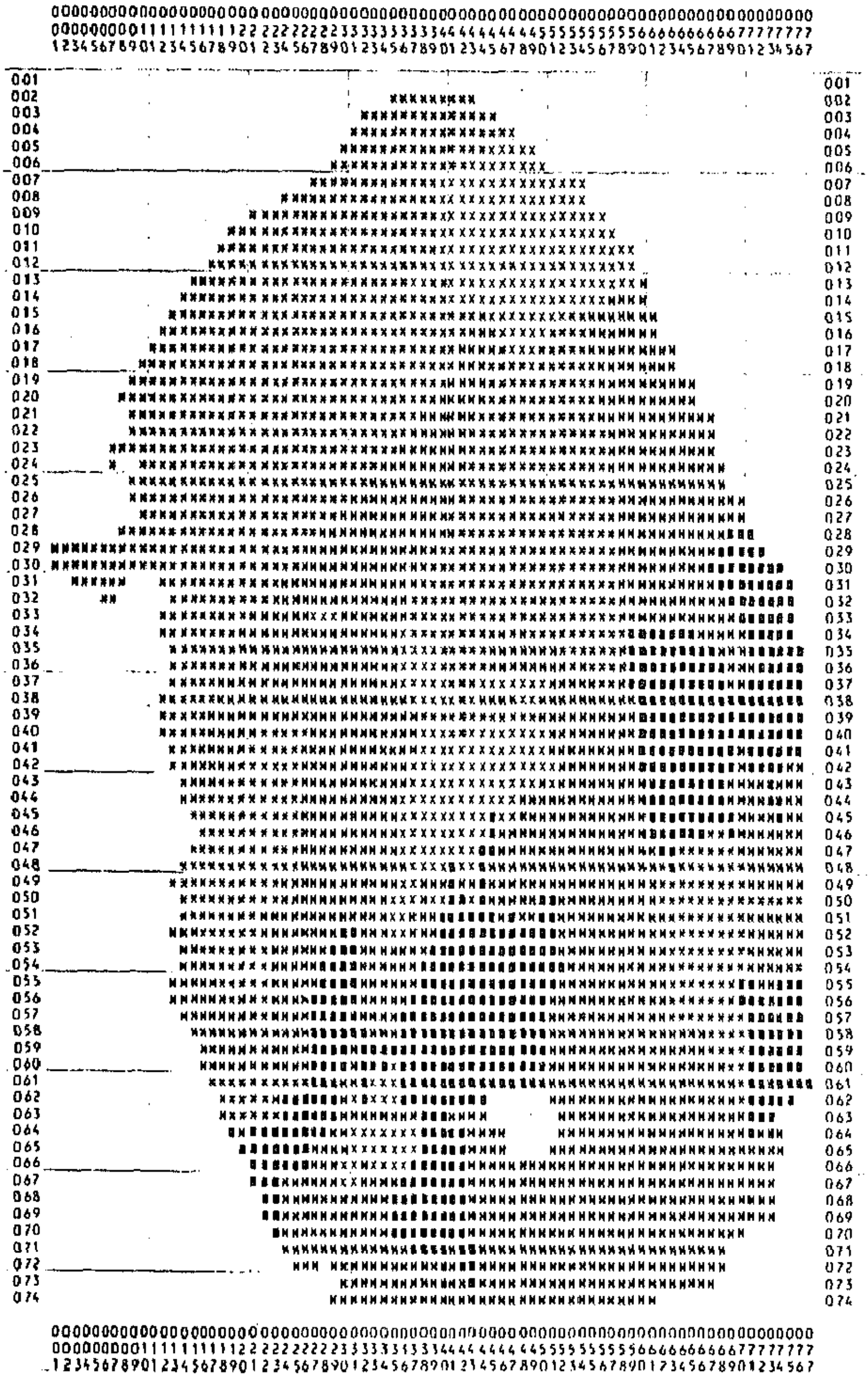


Fig. 3.2.5 Social Land Use Division

NUMBER

LEVEL	SIGN	NUMBER
0	x	123
1	*	132
2	x	2875
3	H	698
4	■	107
ERROR		1763

Others
Forest or grass land
Farm land
Yard areas or semi-important structure are existing
Urban areas or important structures-national road, trunk channel etc—one existing

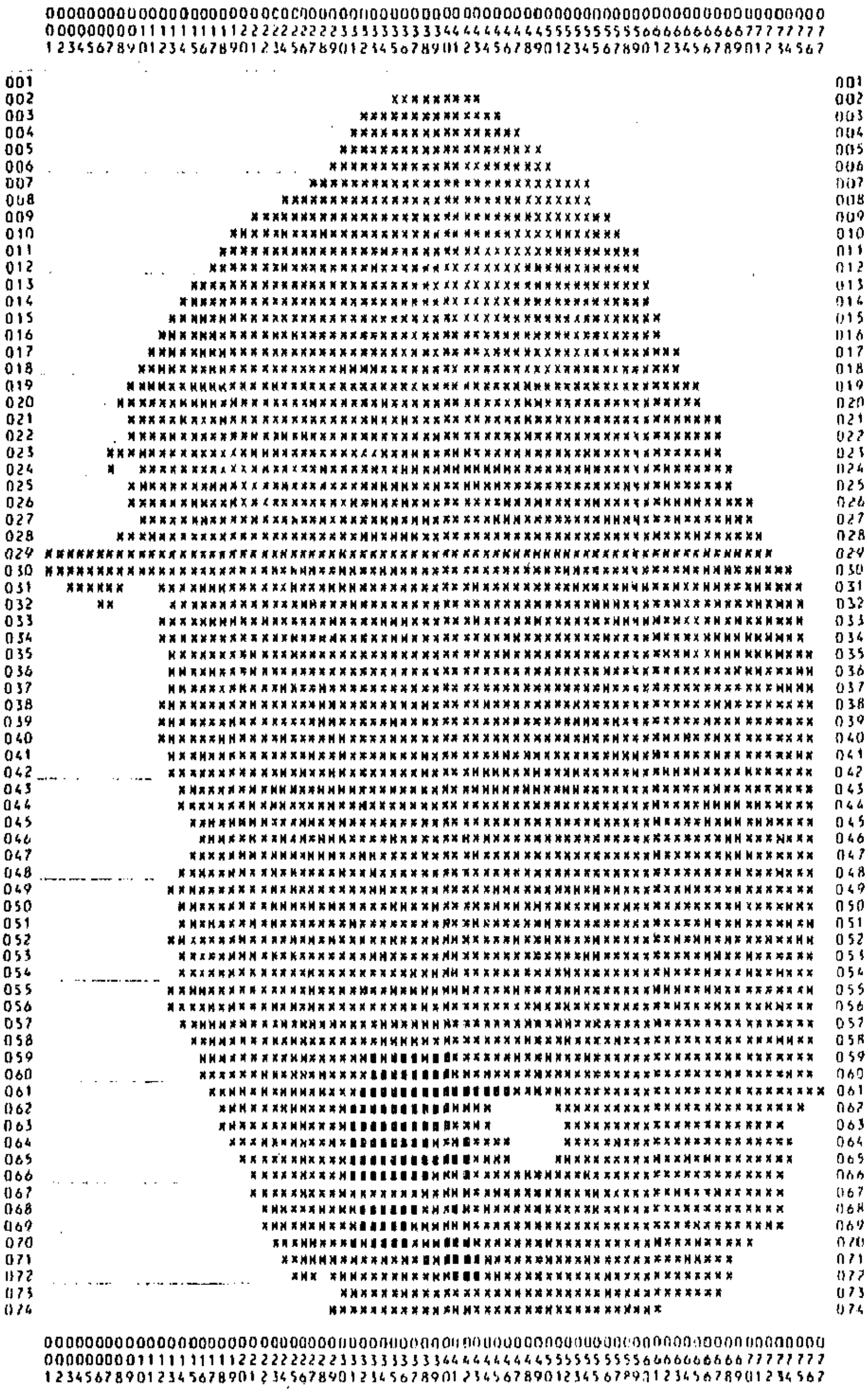


Fig. 3.2.6 Economic Land Use Division

NUMBER

LEVEL	SIGN	NUMBER	
0	x	85	Forest or glass land and others.
1	x	137	Dry field (in 25—50%)
2	x	899	Dry field (in 50—100%)
3	H	675	Yard or Paddy field (in 25—50%)
4	■	2139	Urban area or paddy field (in 50—100%)
	ERROR	1765	

Fig. 3.2.7 Irrigation Areas Division

NUMBER

LEVEL	SIGN	NUMBER	
0	X	816	Dry field or forest etc.
1	*	1041	Primitire or non-technical irrigation area
2	x	1262	Semi-technical irrigation area
3	H	0	—
4	▮	816	
	ERROR	1761	Technical irrigation area

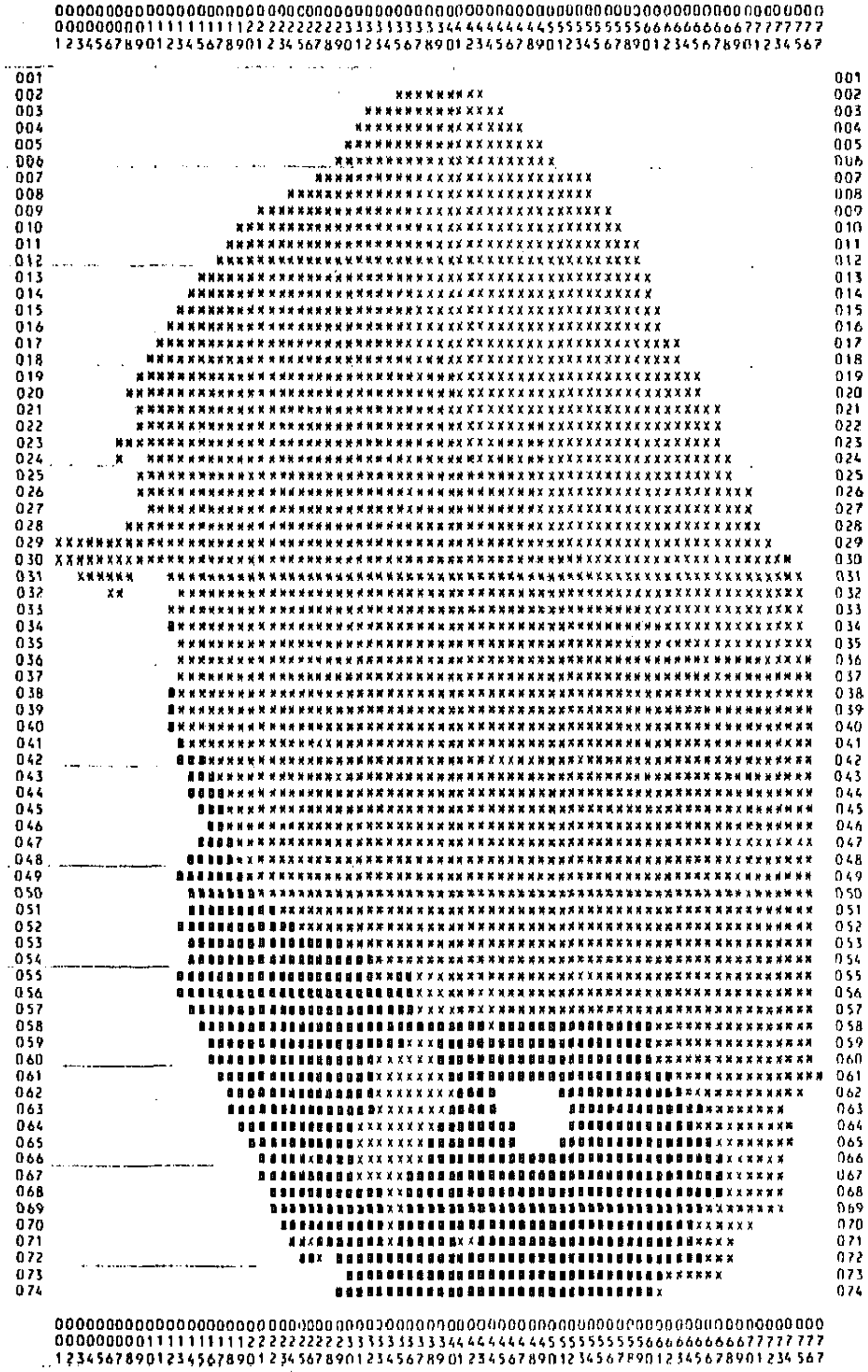


Fig. 3.2.8 Possible Hazard Areas Division (From geomorphic aspects)

NUMBER

LEVEL	SIGN	NUMBER		
0	x	2246	Where outside of the hazard areas.	
1	*	25	Where the hights of bank of flooding point	over 20 meter
2	x	95	"	in 10 — 20 meter
3	H	257	"	in 5 — 10 meter
4	■	1312	"	in 0 — 5 meter, or nuee ardente zone
	ERROR	1763		

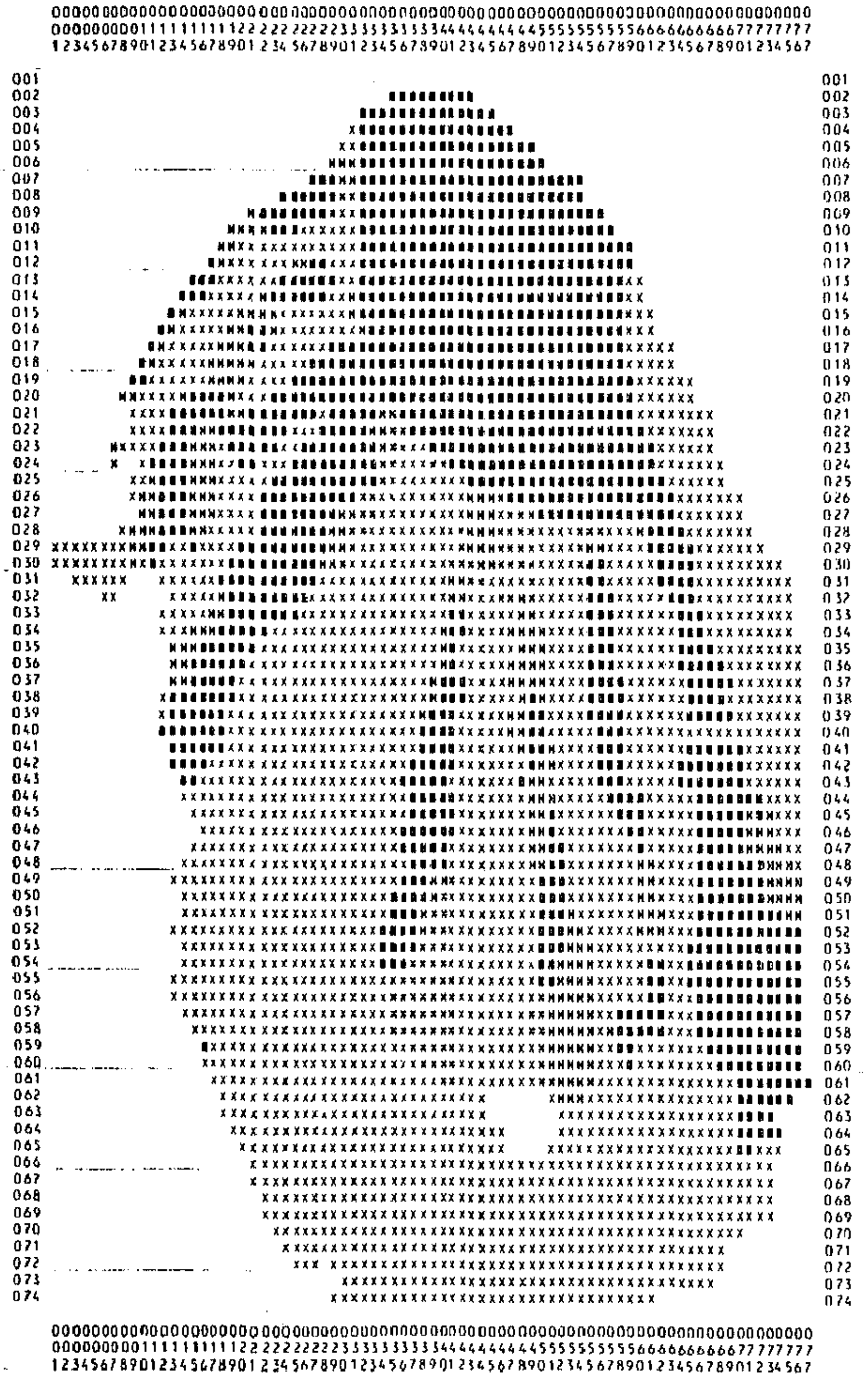


Fig. 3.2.9 Slope Grades Division

NUMBER

LEVEL	SIGN	NUMBER			
0	x	202	Slope gradient	over 25	degrees
1	x	35	"	in 15 – 25	"
2	x	155	"	in 8 – 15	"
3	H	731	"	in 3 – 8	"
4	■	2764	"	in 0 – 8	"
	ERROR	1763			

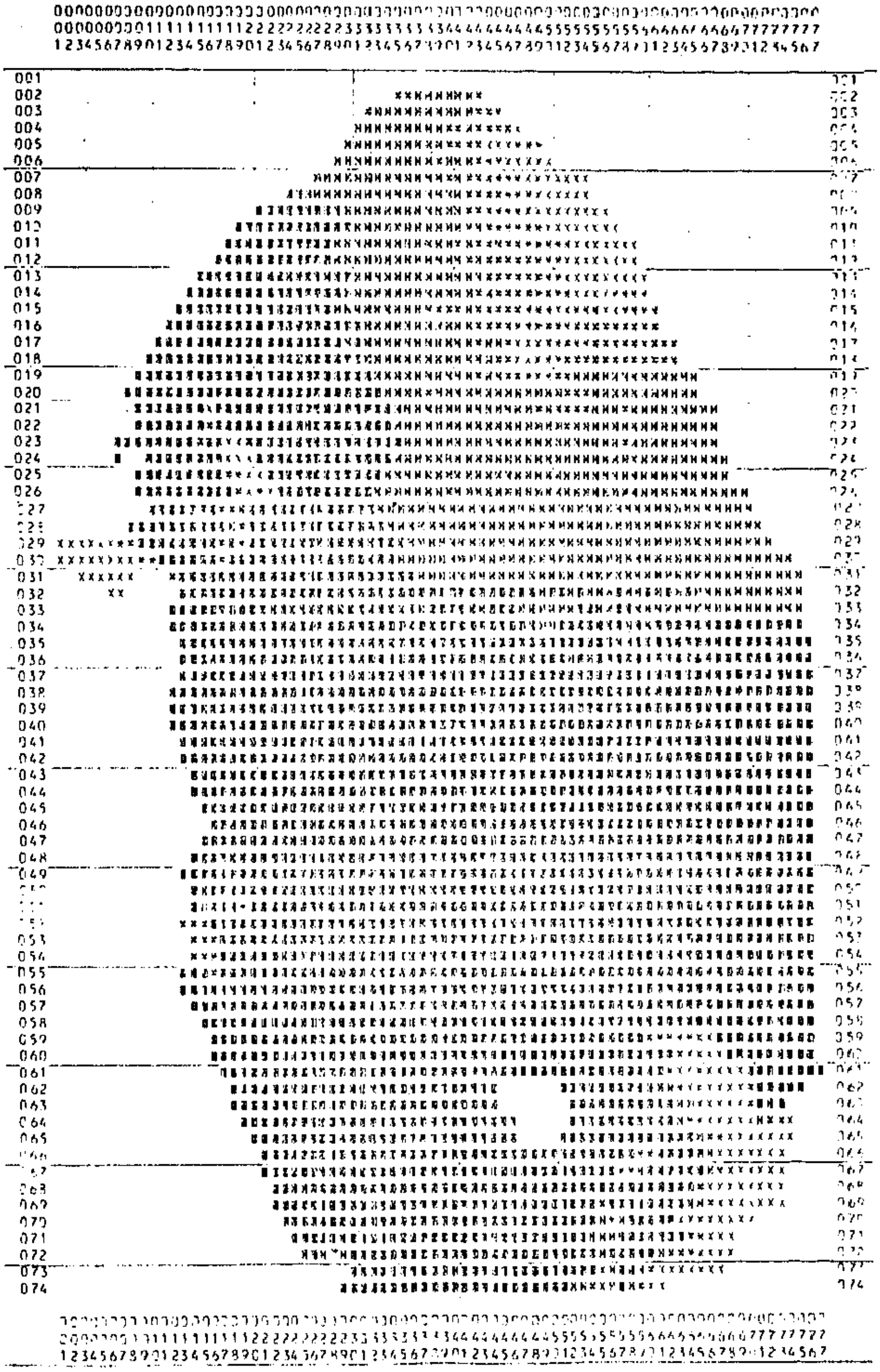


Fig. 3.2.10 Degree of Danger Classification

NUMBER

LEVEL	SIGN	NUMBER		
0	x	2225	Degree 1 of danger classification	(least dangerous area)
1	*	106	" 2 "	
2	*	476	" 3 "	
3	*	715	" 4 "	
4	*	413	" 5 "	(most dangerous area)
ERROR		1763		

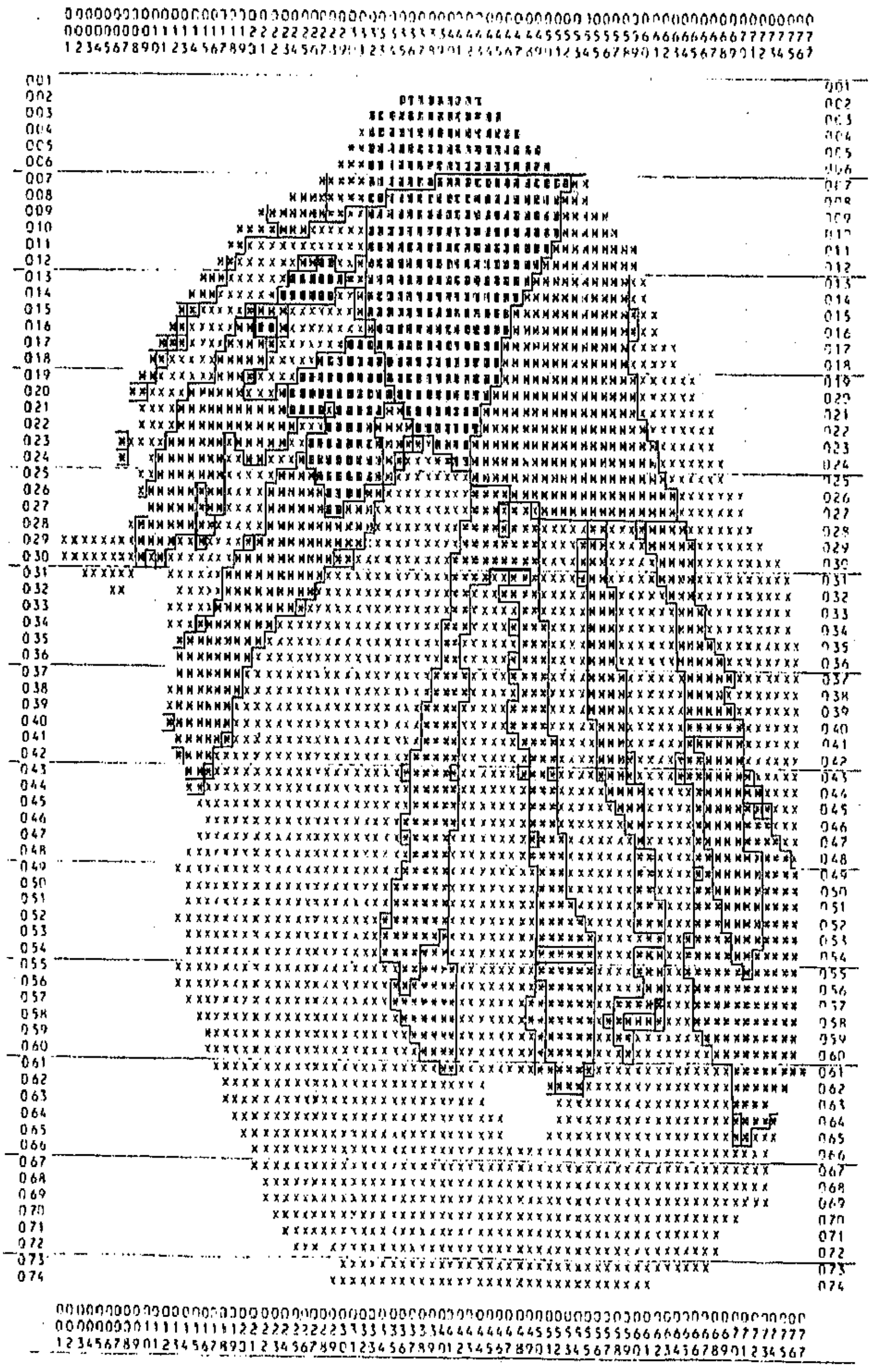


Fig. 3.2.11 Degree of Social Importance Classification and Hazard Areas

NUMBER

LEVEL	SIGN	NUMBER		
0	x	233	Degree 1 of solal importance classification	(least important area)
1	*	678	" 2 "	
2	*	2229	" 3 "	
3	X	517	" 4 "	
4	■	115	" 5 "	(most important area)
	ERROR	1763		

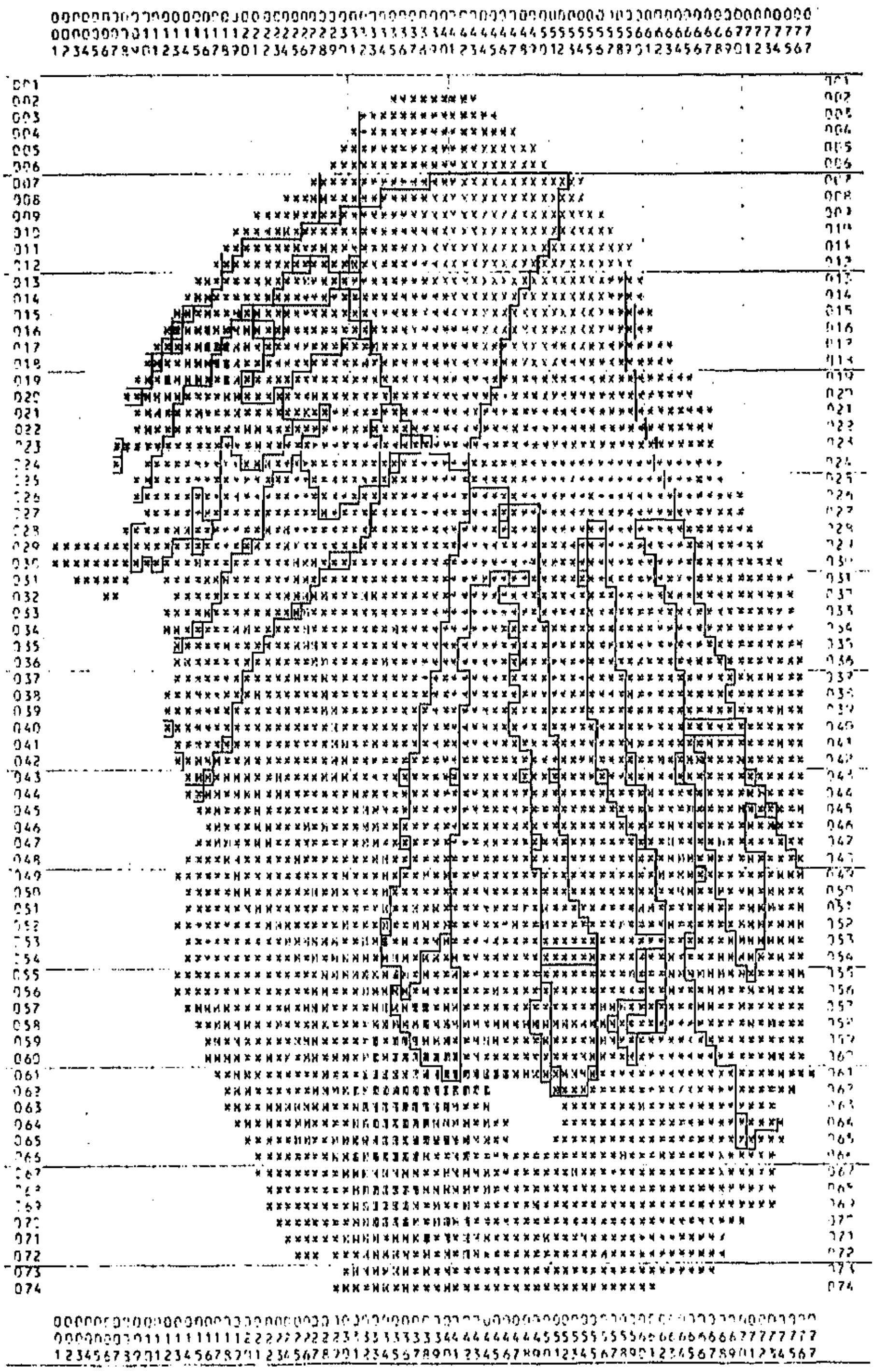


Fig. 3.2.12 Degree of Economic Importance Classification and Hazard Areas

NUMBER

LEVEL	SIGN	NUMBER		
0	x	170	Degree 1 of economic importance classification	(least important area)
1	×	145	" 2 "	
2	*	1383	" 3 "	
3	x	2027	" 4 "	
4	■	210		
ERROR		1763	" 5 "	(most important area)

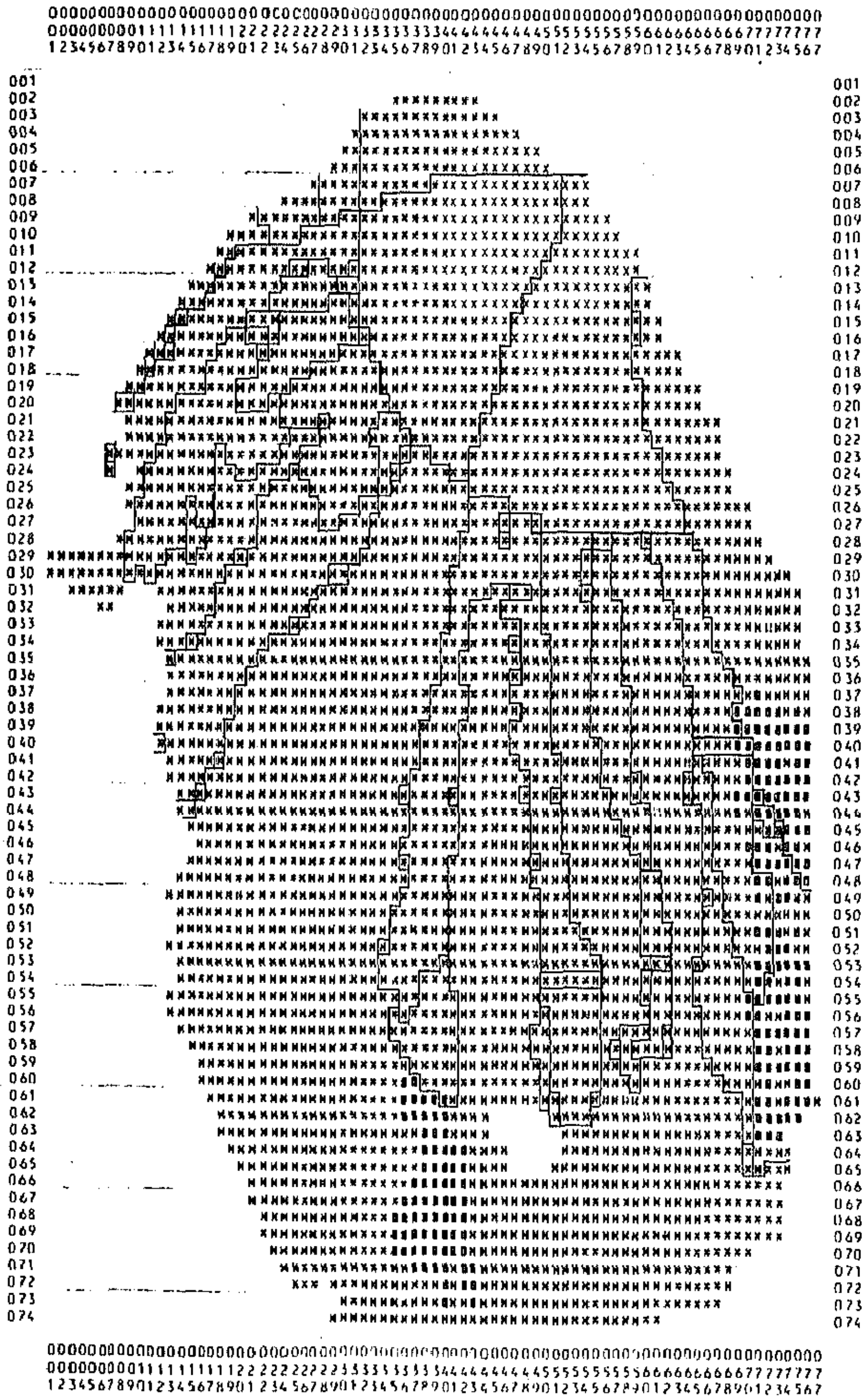
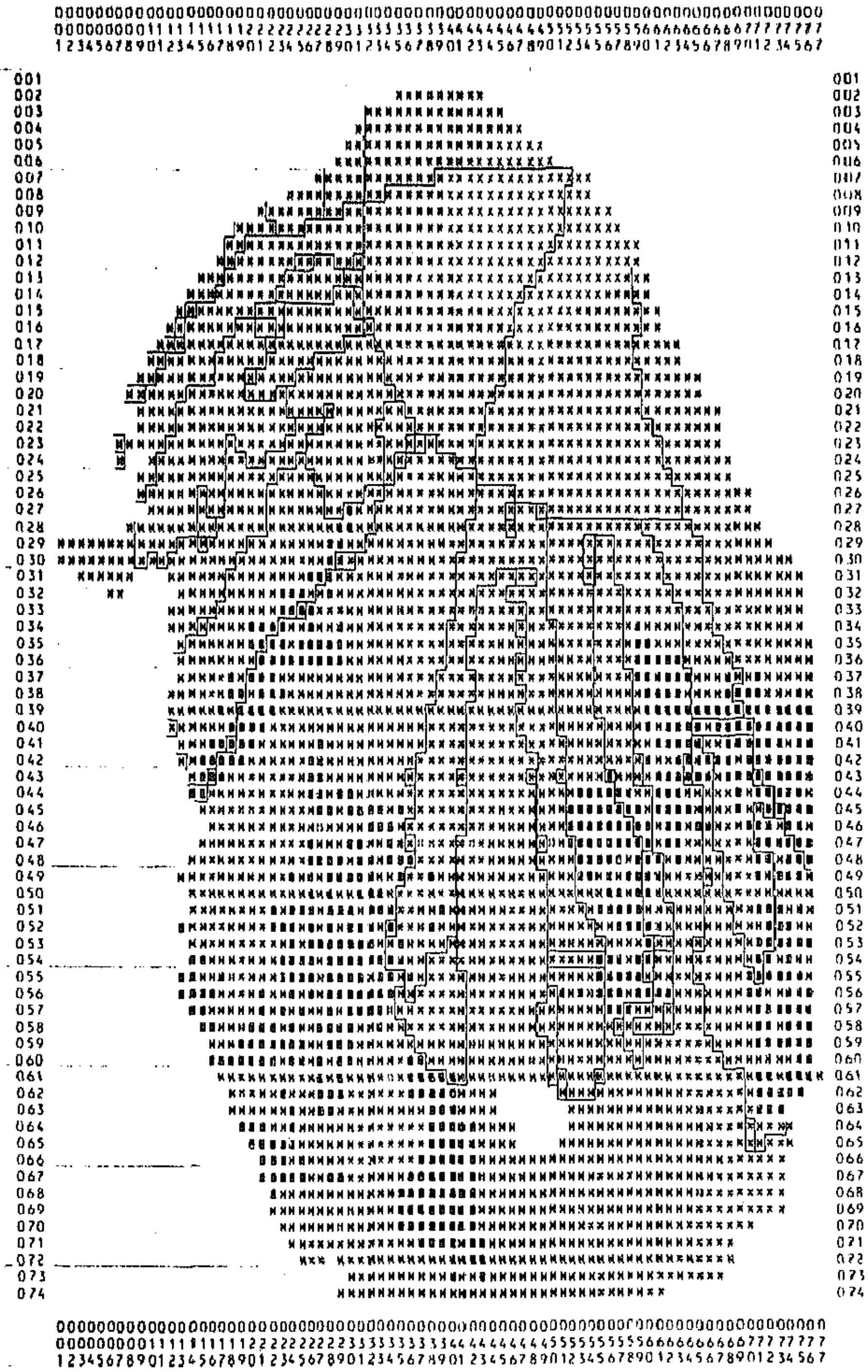


Fig. 3.2.13 Degree of Future Economic Importance Classification and Hazard Areas

NUMBER

LEVEL	SIGN	NUMBER		
0	x	169	Degree 1 of future economic importance classification	(least important area)
1	x	118	" 2 "	
2	x	1174	" 3 "	
3	H	1837	" 4 "	
4	■	637	" 5 "	(most important area)
	ERROR	1763		



2) Plan for Land Use Changes and Improvements

In planning future land use, disaster prevention and area development must be considered together. Only the highest 7% of the 900 sq.km on the slopes of G. Merapi, has a slope steep enough (over 15 deg) to necessitate that soil conservation be taken into account in land use planning. Since the slope for about 80% of the study area is under 8 deg., soil conservation will not be much of a problem. On the other hand, some changes in land use will be necessary for disaster prevention and area development.

(1) Change in Land Use in Type-I Nuée Ardente Zone

The type-I nuée ardente is the most hazardous zone in the project area. Although some of the residents moved out after the disaster of 1969, there are still a large number of people engaged in agricultural production. In order to protect their lives and property, an active effort must be made to persuade as many of them as possible to resettle in safer areas. A good deal of the usuable land in this zone is already being used as field for paddy and other crops, but productivity is low, and hence its priority in terms of protection from disaster is also low. The best policy for this area would be to use the land for forests which would favor disaster prevention.

(2) Protection and Improvement of Good Farmland

The term "good farmland" describes any of the following: high productivity areas, areas in which productivity is rising, or areas in which the present and future rate of increase in rice yields is high. (see Figs. 3.2.14-16)

Good farmland must be secured and protected in order to maintain a production basic for the area and stabilize life. The area would profit from and develop more rapidly if the level of production were raised by stabilizing river courses and intakes by means of disaster prevention works.

Fig. 3.2.14 Crop Yield Division and Irrigation Area Divisions

NUMBER

LEVEL	SIGN	NUMBER			
0	x	202	Division	1	Very low productivity
1	¥	244	"	2	
2	×	327	"	3	
3	H	1574	"	4	
4	▮	997	"	5	High productivity
	ERROR	1763			

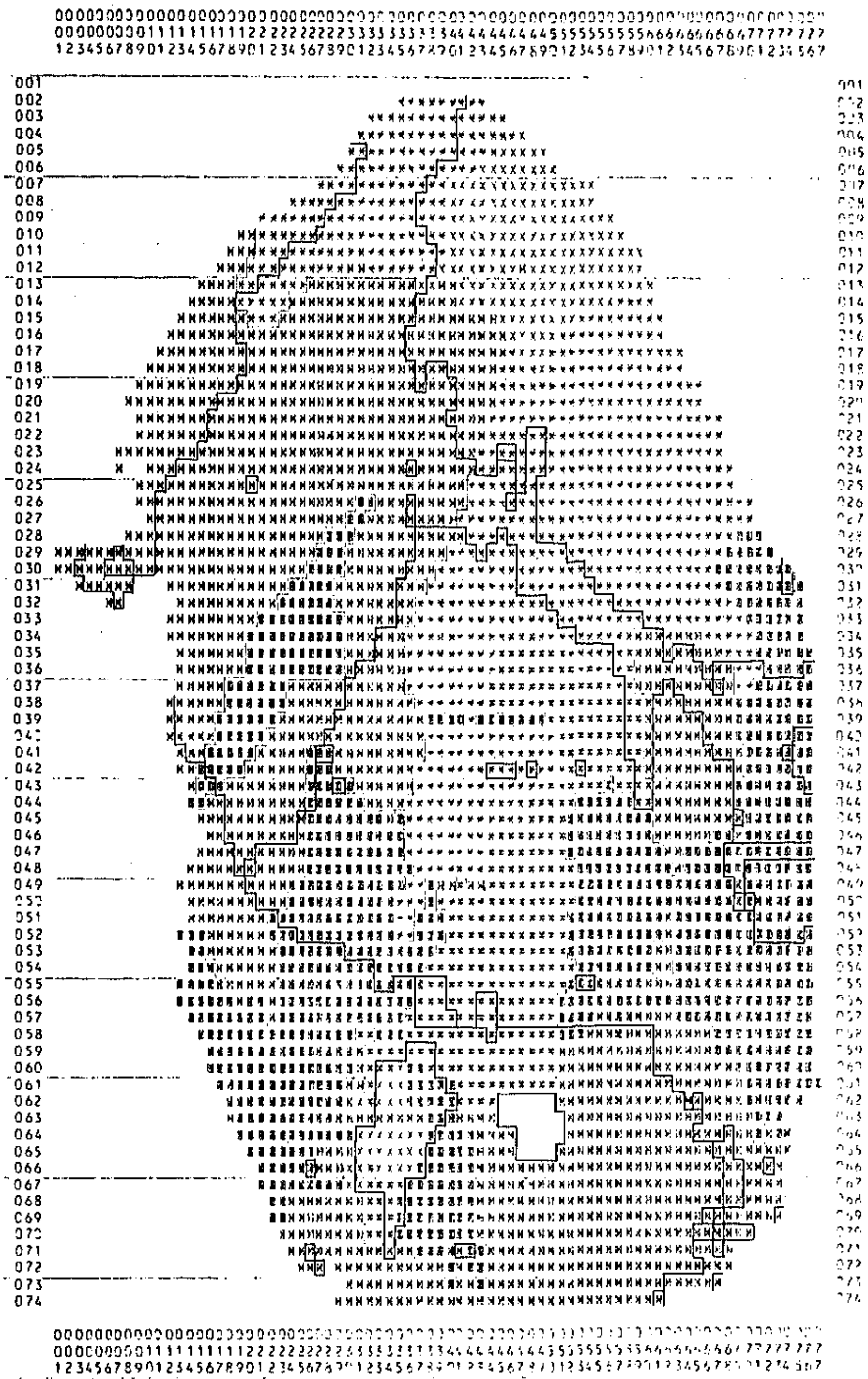


Fig. 3.2.15 Present Tendency of Yield of Paddy (1981) and Irrigation Area Divisions

NUMBER

LEVEL	SIGN	NUMBER			
0	x	213	Division	1	Low
1	*	1127	"	2	
2	x	1816	"	3	
3	¥	373	"	4	
4	■	405	"	5	High
	ERROR	1763			

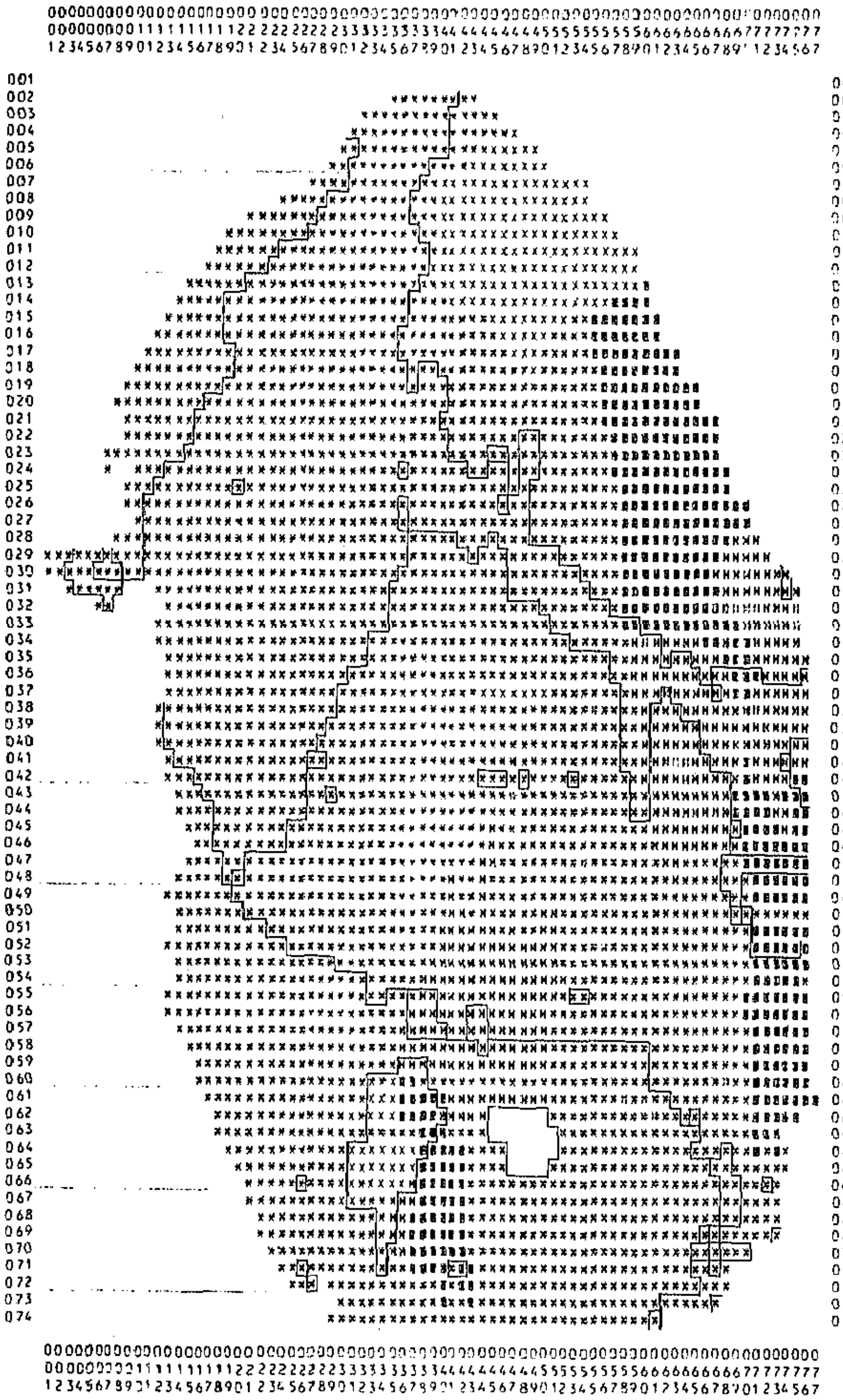
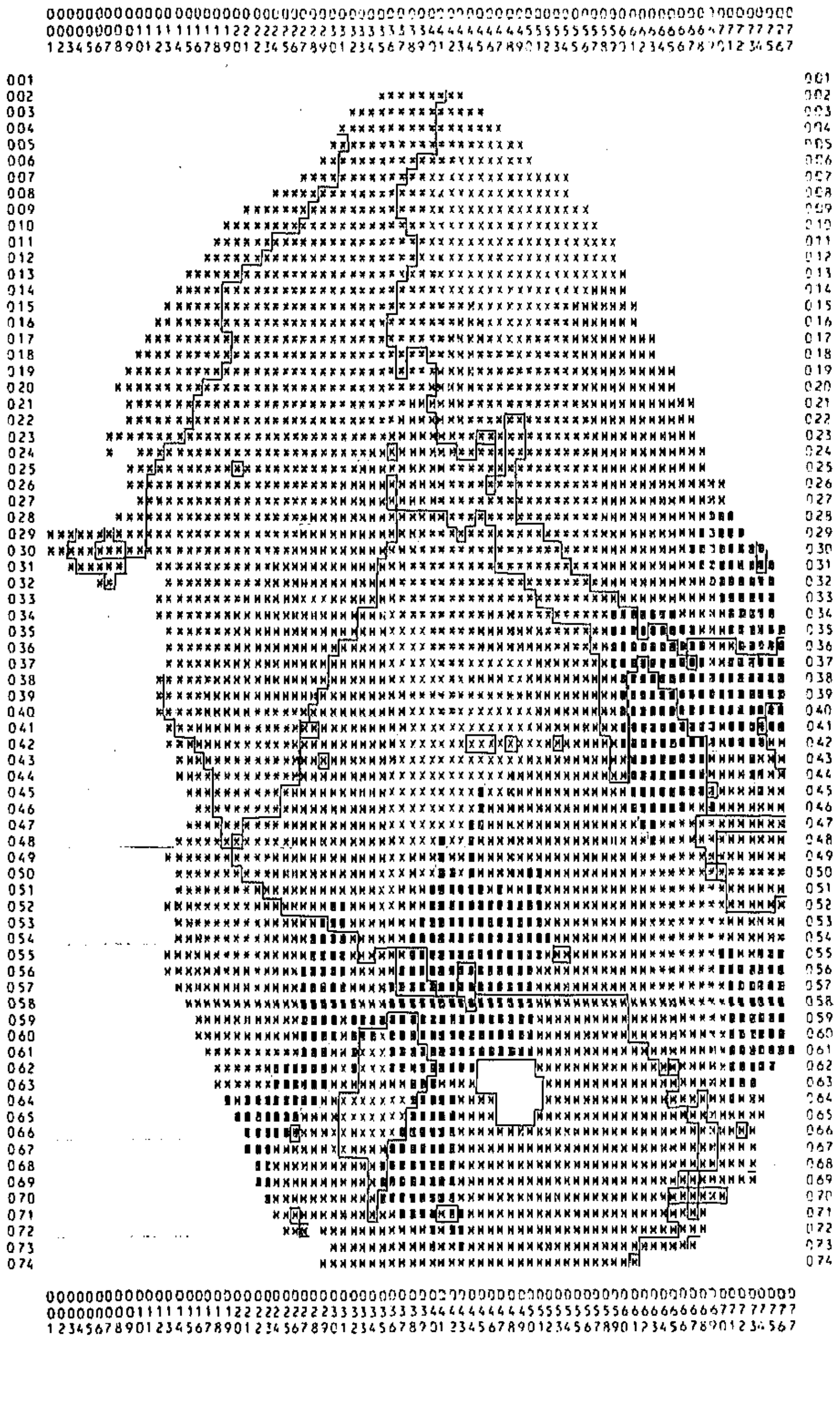


Fig. 3.2.16 Yield of Paddy and Irrigation Area Divisions

NUMBER

LEVEL	SIGN	NUMBER			
0	x	346	Division	1	Low
1	*	245	"	2	
2	x	1095	"	3	
3	x	1655	"	4	
4	#	594	"	5	High
	ERROR	1763			



3) Disaster Prevention Facility (sabo facilities) Plan

a) Purposes of the Plan

i) Prevention of disasters

Since G. Merapi consists of easily eroded volcanic material, lahar flow often occurs with rainfall. The lahar erodes the river bed and banks, increases in scale as it flows down, and floods with enormous energy causing great damage to life, houses, fields, roads, irrigation facilities, and so on. The lahar brings a large quantity of sediment with it that accumulates in river beds, raising the level of the river and thus causing flooding (banjir). Specifically, the sediment flows into K. Progo and other main rivers, raising their beds and affecting their courses, flooding and damaging irrigation facilities.

The disaster prevention facilities will reduce the lahar, and control the excessive sediment discharge to prevent banjir.

ii) Irrigation water supply stability

A stable supply of irrigation water is the key for stabilization and growth of agricultural production in the area.

In this region, however, large quantity of sediment discharge cause river beds to rise and fall and river courses to change drastically. Irrigation intake is consequently unstable; the maintenance and operation of irrigation facilities is costly and time consuming for labor.

With disaster prevention facilities, the rivers could be stabilized and a stable irrigation water supply ensured.

The effectiveness of disaster prevention facilities will be further enhanced by using them for other purposes as well as intake.

iii) Promotion of the area

Since promotion of the area will require ongoing investment and development from a long-term perspective, it is first necessary to secure the safety of the area. In a serious disaster area such as this, disaster prevention measures are a mandatory requirement for area development.

A good example is the K. Woro basin, which used to be subject to serious disasters. Thenks to long years of disaster prevention investment, the K. Woro basin has managed to increase its agricultural income to be four times greater than that of the K. Krasak basin.

iv) Stability of employment

Since disaster prevention works are carried out primarily in low income agricultural areas and since such works continue for a long period, they ofter stable employment and help to develop an area.

b) Areas to be Protected by Means of Disaster Prevention Facilities

The first and foremost purpose of the disaster prevention facilities will be the mitigation and prevention of disasters on the slopes of G. Merapi, mainly along the tributaries of K. Progo, K. Opak and K. Denkeng.

Although such disaster prevention planning is expected to be effective for all three tributaries, the problems with respect to K. Progo and K. Opak cannot be solved by merely checking and regulating sediment discharge. Other countermeasures must be taken since they contain many trouble spots.

c) Scale of the Plan

Usually the scale of a disaster prevention plan is determined by the amount of rainfall and probable flood discharge, but in the case of this area, the dominant factor is the scale of eruption and the resulting amount of sediment discharge.

i) The amount of sediment production and discharge tends to be determined by the amount of volcanic material emitted from the eruptions and the amount of time that elapses between the eruptions.

ii) The scale of flooding is for the most part determined by the amount of decrease in river discharge capacity due to the plugging of valleys and the raising of river-beds.

iii) The scale of the plan will therefore have to be based on maximum amount of sediment discharge experienced in the area. The probability of flood discharge over a period of 100 years will be taken for the design flood discharge for the plan facilities.

d) Disaster Index

Target indices for the disaster prevention facilities will be based on the degree of possible flooding.

	Proposed area	Disaster Index
(1)	Lahar zone of Type - I	Degrees 1-5 of possible flooding area
(2)	Banjir zone of Type - I	Degrees 4-5 of possible flooding area
(3)	Types II - III	Degree 5 of possible flooding area

3.2.2 Sabo Facilities Plan of Selected Model Tributaries

The plan for disaster prevention facilities has been drafted with respect to one model river for each type of area (Type-I, Type-II and Type-III areas). The plan will be finalized after study of the present draft and implementation of the surveys scheduled for 1979.

The rivers that have been selected as models are as follows:

Type-I : K. Krasak
Type-II : K. Woro
Type-III : K. Boyong

The draft of facility plans summerized in the following table and Table 3.2.1 and are explained in detail in the following text.

River	Facilities						Construction Cost (unit: 1,000Rp.; price in 1978)
	Check dams (No.)	Consolidation dams (No.)	Training Levees (m)	Dike (m)	Groin (m)	Others (No.)	
K. Krasak	14	10	7,140	22,200	4,500	1*	7,300,000
K. Woro	10	5	-	11,520	3,000	1**	4,500,000
K. Boyong	5	2	-	6,960	-	2***	1,500,000
Total	29	17	7,140	40,680	7,500		13,300,000

* Lowering the hight of weir by cutting the crown
** Excavating,
*** Construction of bridges

1) Planning for different sediment forms and mechanical features

a) The form classification for sediment are as follows:

(1) The classification from the view point of natural phenomena;

- Nuée ardente
- Lahar
- Banjir

(2) The classification from the standpoint of mechanical features;

- Massive transportation - mud flow and massive flow partly by tractive movement
- Individual transportation - Bedload and suspended load

(3) The classification from the standpoint of river-bed variation,

- Eroding district,
- Sediment flowing district,
- Depositing district,

b) The policies for each in the disaster prevention facilities plan are as follows:

i) Nuée Ardente

Since this form is not easily dealt with by means of disaster prevention facilities, it is not considered in the present plan.

ii) Lahar

Lahar occurs primarily above the altitude of 1,000m and flows down to about the 400m, gaining in scale and energy as it erodes the river-bed and banks along the way. Lahar also gives rise to the phenomenon of "river piracy" because of sand plugging, erosion and jumping over river banks. This phenomenon drastically changes the shape of the river downstream, which can be very hazardous, because it considerably alters the area of the basin and the river regime.

Possible countermeasures are listed below:

(1) fixation of the valley outlet for stabilization of the course of Lahar flow and prevention of the occurance of lahar.

(i) Fixation of Valley Outlets

By providing check dams and training levees at valley outlets, it will be possible to bring the river into a single, stable river course further downstream. This measure is planned for Type-I areas, where the phenomenon of river piracy is particularly pronounced.

(ii) Prevention of Expansion of Lahar

The lahar flow continuously expands along the way because of extreme lateral and downward erosion.

In fact, about 95% of the sediment produced in the case of K. Bebeng in the period 1969-1976 was due to such erosion. Accordingly, check dams and consolidation dams will be built and river-bed fixation works undertaken in order to raise the river-bed through the storage of sand, widen the river course, and reduce the stream gradient for the purpose of checking erosion and reducing the energy of the lahar flow. In this way the scope of the lahar flow can be reduced.

(iii) Reduction of the Scope of Lahar Flow and Prevention of Overflow

The basic measures for coping with lahar will be those of (i) and (ii) above. If rivers might cause damage from lahar overflow in spite of such measures, the scope of flow of the lahar will be reduced by providing sand pockets. Also embankments and levees should be planned for the prevention of such overflow.

(2) fixation of the channel for narrowing the width of flow and prevention of overflowing.

(3) Prevention of occurence will not be considered, since lahar occurs above 1,000m in the nuée ardente zone where disaster prevention facility construction would be dangerous.

iii) Banjir

In Banjir districts, the sediment is transported and deposited. Overflowing due to insufficient flow capacity and collapse of embankments and levees owing to meandering and and irregular flow are very pronounced.

There are two causes of insufficient flow capacity;

° Reduction of flow capacity caused by sedimentation

° Sharp increase of outflow and sediment discharge owing to eruptions or river piracy.

Possible countermeasures are listed below:

(1) As already mentioned in the section regarding lahar,

the most basic countermeasures are reducing sediment products and controlling sediment discharge through the use of check dams and sand pockets. The countermeasures to be discussed here are additional ones for banjir areas.

(2) Improvement of River Courses

In banjir areas an ideal situation of the river courses are characterized by little river-bed variation, meandering, or drift, for smooth flow of water and sediment without overflowing or the collapsing of banks. The measures to be applied are therefore mainly the following:

- Embankments

  Embankments are to be provided at points where there is a deposit tendency and points where flow capacity is insufficient.

- Improvement of Sharp Curves and Bottlenecks in the River Course

  Such improvement will be undertaken at sharp bends, bridges and intake points, where flow capacity is impeded by a narrowing of the course.

- Lowering of River-Beds by Increasing Sediment Flow Capacity

  At points where sediment discharge capacity is low (such as points where the stream gradient is small and the river is wide), the river-bed rises owing to the sediment deposits and leads to overflowing. At these points, therefore, embankments, groin, etc. will be provided to narrow the river, increase sediment flow capacity, and lower the river-bed.

- Protection Works of Bank Collapse Points

  The collapsing of river banks will be prevented by means of revetment, groin, etc.

- Storage and Excavation of Sediment Deposits

  In cases where sediment deposits in the river course cannot be handled by the above means, the sediment will be controlled by means of sandpockets and check dams, and removed by excavation.

2) Planning Policy for Reduction and Control of Sediment

A plan for coping with sediment will be formulated to serve as a basis for the planning of the disaster prevention facilities. This plan will show how to cope with the harmful amounts of the sediment production and the sediment discharge in the river basin by means of sabo facilities.

a) Definitions of Basic Sediment Amounts for the Plan

(1) Proposed sediment amount to be produced

This includes deposits from volcanic eruptions, sediment that flow into channels as the result of the collapsing of river banks, and sediment produced by secondary erosion of river-bed deposits.

(2) Proposed sediment amount to be controlled in river course

This is the amount of the sediment produced that is temporarily held back in the river course, thereby adjusting the sediment discharge.

(3) Proposed sediment discharge

This is the amount of sediment discharge that will be carried down by lahar or tractive force to the design basic point.

The amount is calculated as follows;

(Proposed sediment discharge) = (proposed sediment amount to be produced) - (proposed sediment amount to be controlled)

(4) Proposed allowable sediment discharge

This is the sediment amount that can be sent downstream from the design basic point without any harm.

(5) Proposed exceed sediment (sediment amount for the purpose of the plan)

This is the amount of sediment on which the plan will be based. The amount is calculated as follows:

(Proposed exceed sediment) = (Proposed sediment discharge) - (Proposed allowable sediment discharge)

b) Policy for Calculation of Proposed Sediment Amount for Each Type of Area

Each type of area has its own characteristics with respect to sediment outflow. A simulated time pattern for the amount of sediment outflow for each type is given in Fig. 3.2.1.

(1) Type-I Areas

In type-I areas, the sediment discharge is very great immediately after eruption, gradually diminishing thereafter. Peak sediment discharge for type-I is the highest for all three types, and the sediment discharge during an average year is larger than for the other two types.

In areas of this type, the damage is caused by the major sediment discharge immediately after eruption, and if this harmful sediment discharge can be dealt with, there will be no problem with respect to the annual sediment discharge.

- Basic sediment amounts for the purposes of the plan

Since it is considered that direct influence from eruptions will continue to be confined to Type-I areas, the basic sediment amounts for the purposes of the plan are on the same scale as those for the eruption of 1969. Furthermore, the amount of sediment discharge in the normal year is to be helped to expeditiously flow into the main rivers.

(2) Type-II Areas

At the time of major flooding there is a considerable sediment discharge in these areas. In the normal year, the amount of sediment discharge is to be considerable, although less than in the case of Type-I areas.

The sediment in K. Woro in the normal year cannot flow to K. Dengkeng so it is deposited in the upper river course.

- Basic amounts of sediment for the purposes of the plan

  The plan is based on the annual amount of sediment discharge in a year of major flooding. In the case of K. Woro the amount of sediment discharge in an normal year will also be considered.

(3) Type-III areas

In these areas there is considerable sediment discharge at the time of major flooding, but in the normal year there is hardly any at all.

- Basic amounts of sediment for the purpose of the plan will be those for the year in which there was major flooding.

c) Equation for Dealing with Sediment Amount

The plan for coping with sediment will consist of the following:

1) a plan for reducing with sediment product
2) a plan for control of sediment dischrge and
3) a plan for reducing the amount of sediment discharge.

The equation for dealing with sediment amount follows:

$$F = Q + A - B - C - D - E$$

where F : Proposed allowable sediment discharge

Q : Proposed sediment discharge of flood at design basic point

A : Proposed sediment amount to be produced

B:: Proposed sediment production to be reduced

C : Proposed sediment amount to be controlled on river course

D : Proposed sediment discharge reduction

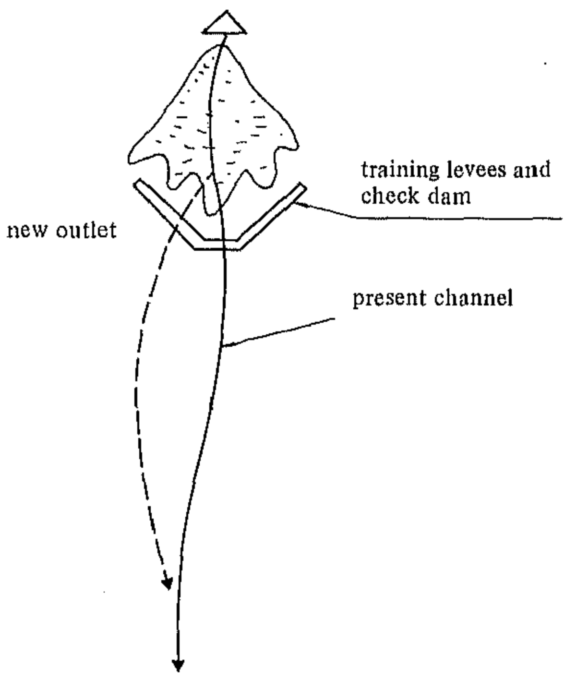
E : Proposed sediment discharge control

d) Plan for Reducing Sediment Product

The sediment product from erosion, collapse, etc. of river-beds and banks will be reduced by check dams and other facilities.

1) Construction work for consolidation of valley outlets

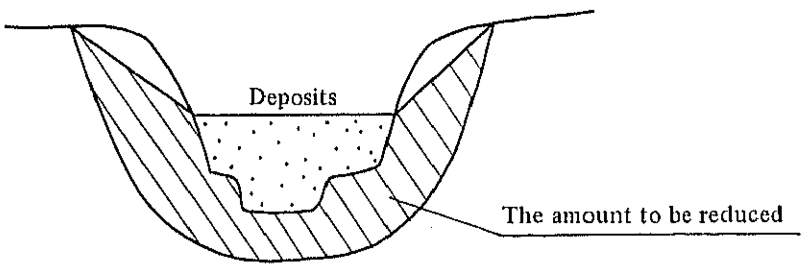
By fixing the valley outlets by means of training levees and disaster prevention dams and directing the flow course along the present channel, it will be possible to prevent the opening of a new outlet through erosion. Protection forest belts will be provided near the training levees in order to check the sediment. Since the present river course has already been eroded and still has a large flow capacity area, future erosion of it will be comparatively minor. If, however, a new valley is opened, there will be erosion of a considerable amount of sediment product. The amount of sediment production to be checked has therefore been calculated as the difference between the amount of sediment production that would result from lahar flow along a new river course and that along the present one.

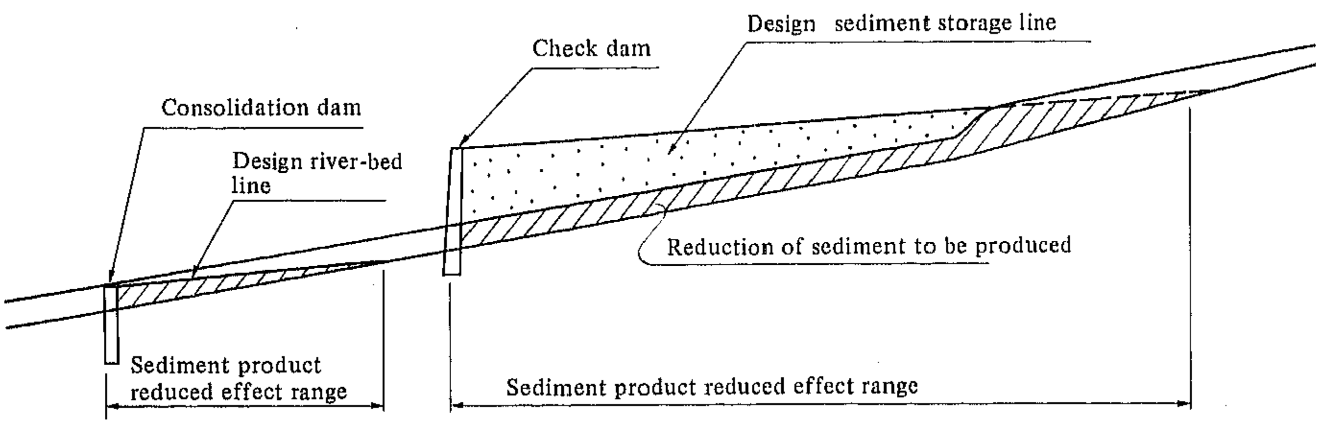


Check dams and consolidation dams

- Possible downward and lateral erosion will be reduced by these means. The reducing effect range will be the point of intersection of the design sediment storage line in the case of check dams (or cosolidation dams) and the design river-bed line of the unstable deposits that is subject to erosion.

  The effective range is explained in following illustration.





e) Plan for Controlling of Sediment Discharge

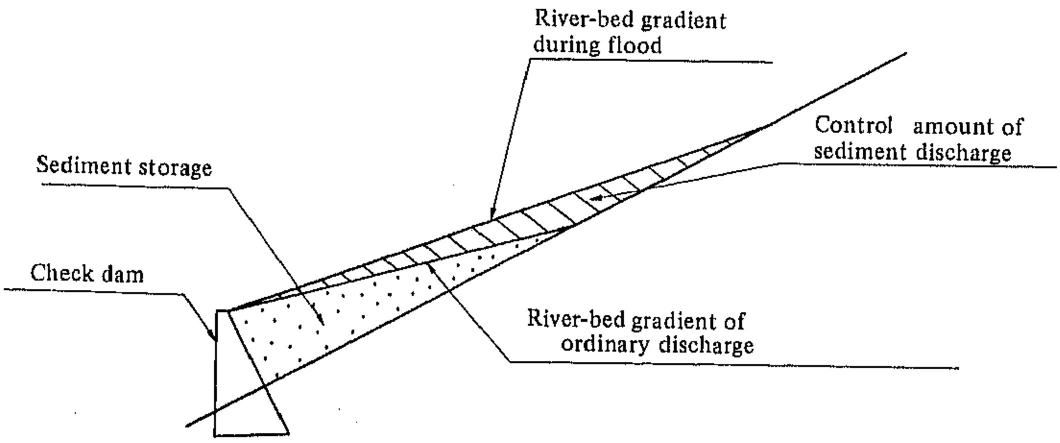
(1) Controlling effect

Sediment discharge will be adjusted by temporarily holding back sediment outflow during flooding by means of sand pockets and check dams for gradual release later on by ordinary discharge.

By means of sediment deposits, the river-bed gradient will be raised sharply during flooding, when sediment concentration is high, and lowered afterwards for the ordinary discharge, when the sediment concentration is low. The amount of sediment control is to be explained as the difference between the river-bed gradient during flooding and the river-bed gradient of ordinary discharge.

The gradients of upper stream by the existing check dams in the Merapi area are shown in Fig. 3.2.2. In the case of Type-I and II rivers the sand accumulation gradient is 2/3-3/4 of that of the river-bed prior to construction of the dam, and over 1/1 in the case of K. Krasak. In the case of Type-III rivers it is 1/2-2/3.

For controlling large amounts by check dams there must be a considerable difference between the sand accumulation gradients during flooding and after flooding, and plenty of time for the sand accumulation gradient during flooding to return to the ordinary gradient.



(2) Planned amount of sediment control

- Since in Type-I and Type-II areas, the amount of sediment consisting of fine particles is considerable, the amount of control by check dams is not to be taken into account in the planning.
- It will be taken into account, however, for Type-III areas since such control is expected.
- The amount of control will be taken into account for sand pockets.

f) Plan for Reducing Sediment Product

As for the amount of sediment storage of check dams and sand pockets, there is a high probability that the sediment storage capacity will be full before flooding, and therefore it will not be taken into account in the planning.

(3) The following points will have to be kept in mind in the planning, design, and execution of disaster prevention facility structures:

(1) Height of the check dams

The ground that will serve as the foundation for the disaster prevention dams consists almost entirely of unconsolidated lahar deposits and pyroclastics. Such a foundation will not be a very good one because of its low bearing capacity, high permeability, and weakness for scouring. For this reason the height of the dams is to be less than 15m. In cases where it is necessary that the height be over 15m, the check dam will have to be built on the sand deposits of another dam, and in this case the height will have to be kept below 10m since the foundation will be even worse. If the bearing capacity and the creep length are insufficient, it will be necessary to widen the base of the dam and lengthen the apron and design the cutoff.

2) Prevention works for check dams and consolidation dams from souring

Because of change in hydraulic conditions, including reduction in the amount of sediment caused by check dams and the like, there is invariably downward scoring of such facilities. Since the river-bed is composed of fine particles, which are particularly susceptible to such action, due care must be taken from the outstart with respect to construction work to safeguard against it. As a rule, a second apron will also be planned for.

(3) Foot protection of revetment and groin

Foot protection work will be planned for points where there might be scoring of revetment or groin. In planning for groin, revetment work must also be planned.

(4) Protection works for wings of check dams

Since the wings of dams are easily destroyed by the shock force of lahar, they must be protected against such shock with banking and revetment work.

(5) Protection crowns of check dams and consolidation dams

Since the crowns of dams suffer a great deal of abrasion and damage from sediment flow, they will be reinforced with stone material, intensive concrete, or other like materials.

(6) Local materials and construction execution

In structural planning, a maximum effort will be made to select materials such as stone, earth, bamboo, wood, etc. and use manual labor from the standpoint of local economy and employment. Furthermore, it will be necessary to utilize construction methods best suited to local conditions.

(7) Flexible staged implementation of the plan

Disaster prevention construction work has a great influence on the amount of sediment load and river-bed variation. Moreover, in view of the fact that many phenomena cannot be foreseen in the planning stage, implementation of the construction work should be flexible, with adequate observation of river conditions at all times. In the case of high dams, for instance, the construction work might be divided into two stages at least in order to better able observe the effects and it even might be necessary to consider planning an additional dam not previously thought necessary.

(8) Multi-purpose use of disaster prevention facilities

The disaster prevention facilities should be planned in such a way as to enable their additional use for intake of irrigation water and other purposes besides disaster prevention.

Table 3.2.1 Summary of Construction Cost and Sediment Disposal

River	Case	Construction Cost (Rp. x 1,000)	Volume of Sediment Production Suppression (m^3)	Volume of Discharge Reduction (m^3)	Proposed Sediment Discharge Control (m^3)	Remarks
K. Bebeng	I	7,300,000	5,081,000	(562,000)	2,999,000	Through K. Bebeng
			729,000	(307,000)	3,154,000	Through K. Krasak
	II	7,700,000	5,330,000	(1,355,000)	2,750,000	Through K. Bebeng
			729,000	(307,000)	3,154,000	Through K. Krasak
	III	8,200,000	5,455,000	(2,597,000)	2,625,000	Through K. Bebeng
			729,000	(307,000)	3,154,000	Through K. Krasak
K. Woro	I	4,500,000	1,737,000	1,500,000 (2,522,000)	1,986,000	
	II	4,800,000	"	" (")	"	
	III	4,600,000	"	" (")	"	
K. Boyong		1,500,000	501,000	(197,000)	269,000	

* Figures in ( ) are excluded out of the sediment disposal plan

Fig. 3.2.1 Sediment Discharge Amount Time Series

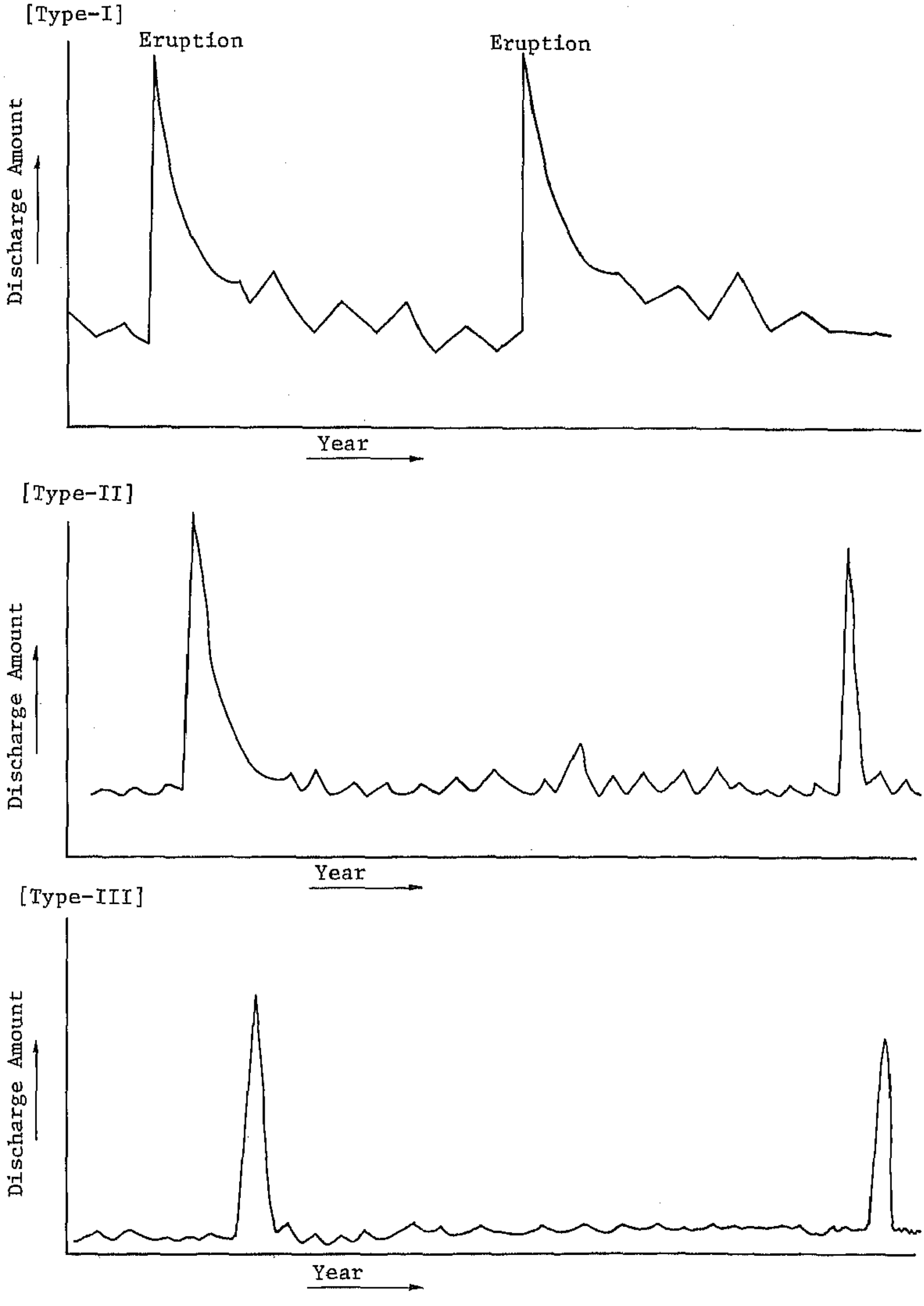
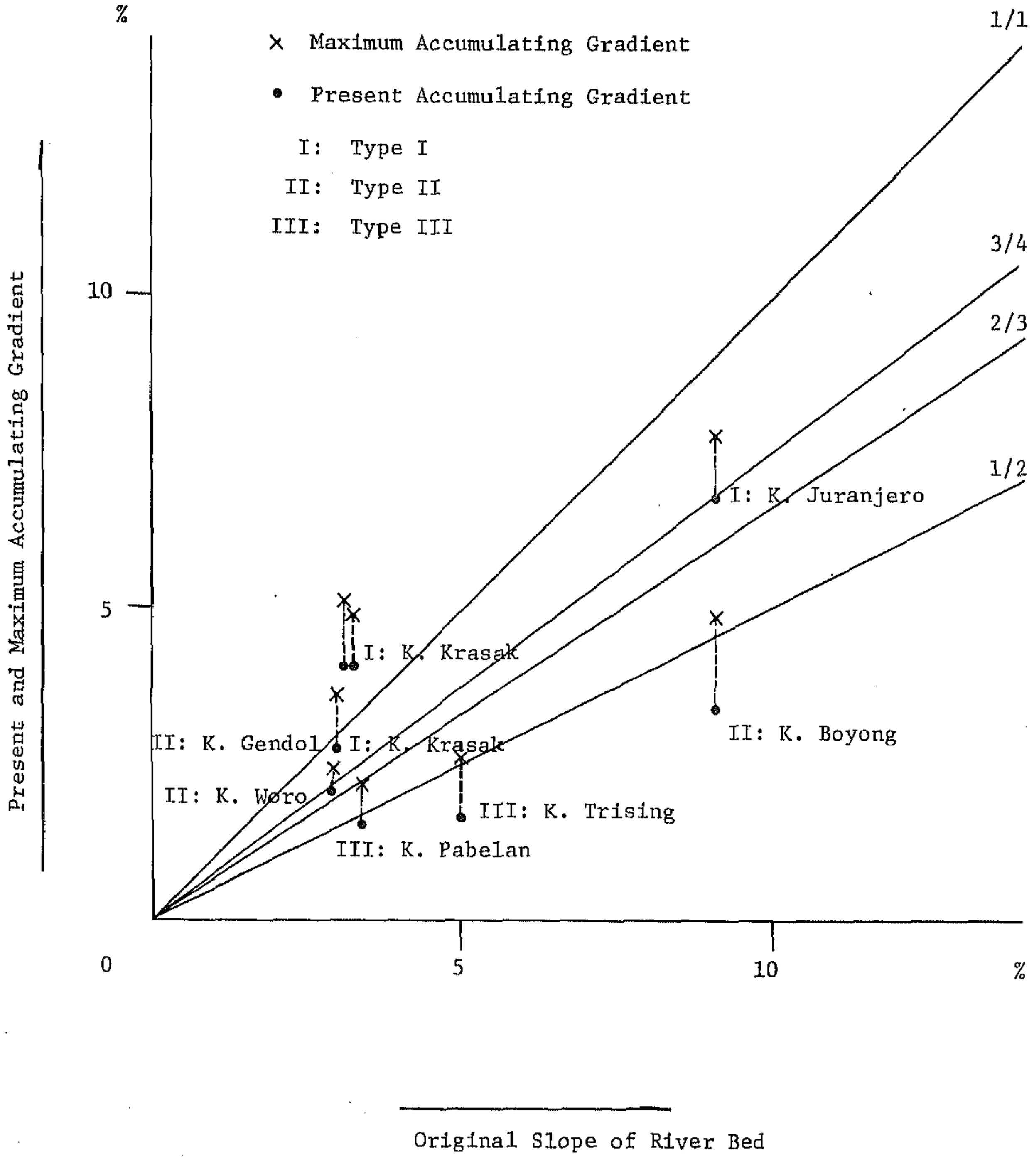


Fig. 3.2.2 Comparison between Original Slope of River-Bed and Present Accumulating Gradient at Site above Check Dam



A. TYPE-I K. KRASAK
Sabo Facilities Location Plan

1. Characteristics of the Basin

(1) Dimensions

The dimensions of the basin are as follows:

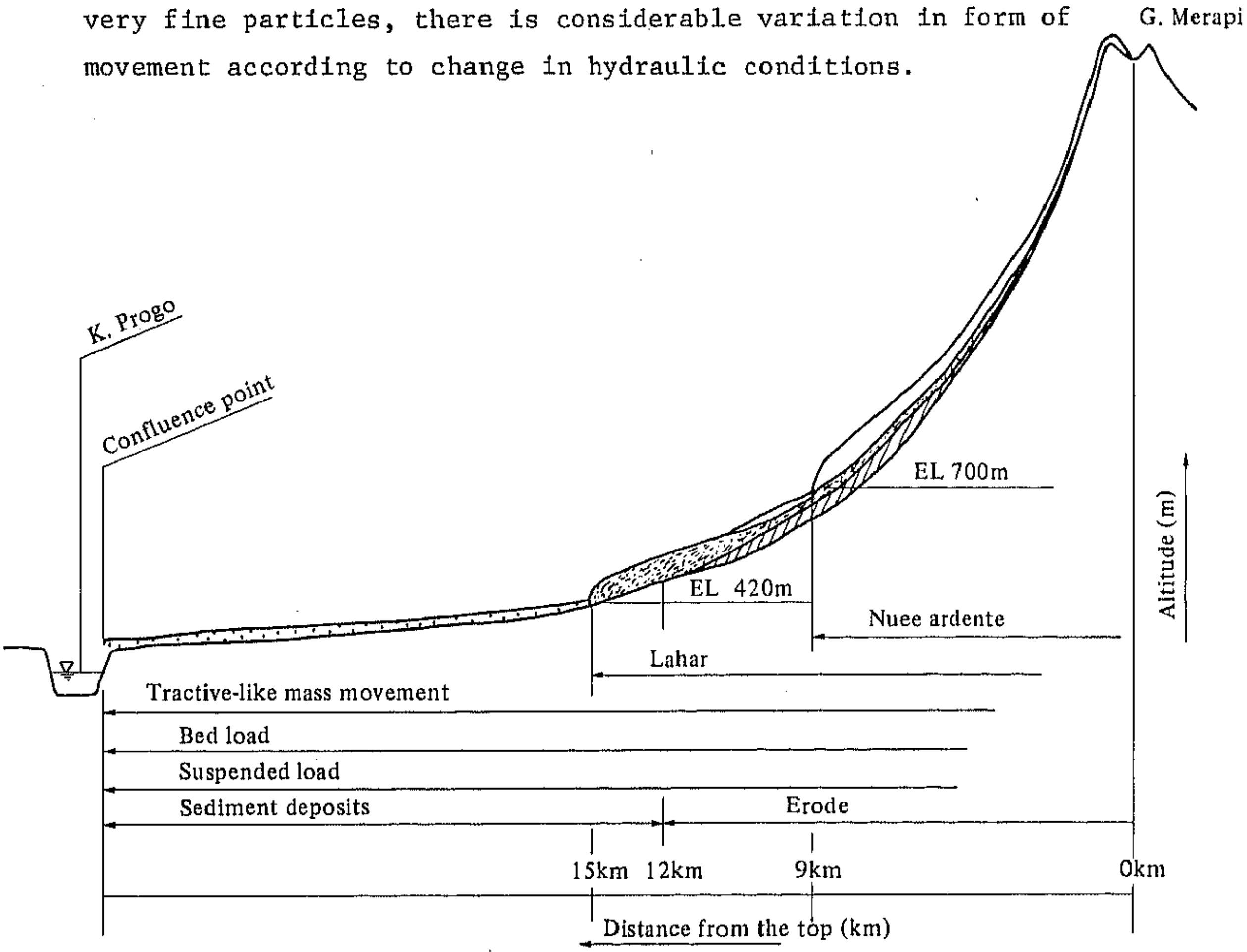
- Basin : $31.7km^2$
- Stream length : 22.0km
- Mean stream gradient : 10.2%
- Design flood discharge : $530m^3$

(2) Influence of Volcanic Eruptions

This is the area which has been most affected by eruptions and such a situation is expected to continue for the time being.

(3) Form of Sediment Transportation

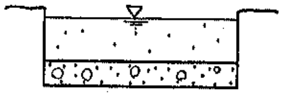
Since the characteristics of sediment transportation involve very fine particles, there is considerable variation in form of movement according to change in hydraulic conditions.



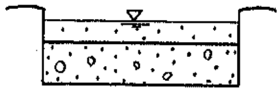
a) Tractive Massive Transport

While the sediment and water flow separately, the sediment flows with tractive-like mass movement.

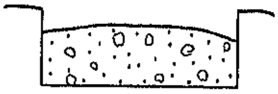
- Individual movement (bed load suspended load)



- Tractive-like mass movement



- mass movement (mud flow)



The equation of conditions of occurence of tractive-like massive movement is explained as follows:

$$I = \left[\frac{C^*(\gamma - \rho)}{C^*(\gamma - \rho) + \rho(1 + \frac{h}{\sigma})}\right] \tan\phi$$

where C^*	:	unit sediment amount (%)
h	:	water depth
d	:	diameter of particle
I	:	(tan I) stream gradient
σ	:	Density of particle
ρ	:	Density of water
$\tan\phi$	:	angle of internal friction

Using this equation, the minimum water depth of tractive massive transport in the vicinity of the river mouth of K. Krasak, was calculated as 60 ∿ 70cm.

When the flood stage is 1.5 ∿ 2.0m in depth for the design discharge, the form of sediment becomes completely the tractive-like mass movement.

b) Suspended Load

The river bed consists of fine particles, the influence of suspended load is the great. At Blaburan in the down-stream area of K. Krasak, where the mean diameter of bed materials is 0.475mm, sediment become suspended load when the rate of flow is over the value of $250m^3/s$. With a design flood discharge of $560m^3/s$ and probability of 100 years, the load will be completely suspended load.

c) Problems in Calculation of Sediment Load

There are many different ways of calculating suspended load and bed load. However in the case of massive transportation only the areas of occurence can be estimated since there is no way of calculating sediment load.
Accordingly, for this area the amount of sediment discharge during flooding must be estimated by methods, which are based on river-bed variation, or actual observation of the amount of sediment discharge. It should be possible to get a rough idea of the amount of individual transport at the ordinary water level.

The basic amount of sediment for the purposes of the plan will be determined primarily on the basis of the results obtained from the river-bed variation survey, ground survey and field survey. Any allowable sediment discharge will be based on the calculated value of suspended and bed load.

(4) River-bed Variation and Overflowing

As a result of the eruption of 1969, there was a marked rise and overflowing in the river-beds of K. Krasak and K. Putih. Although the river-bed of K. Putih is presently getting lower, the river-bed of K. Krasak is rising even now in the middle and downstream areas because of the bottleneck form the old weir and the considerable amount of sediment deposited from upstream.

In the vicinity of the 20km point upstream, the sedimentation is so pronounced that there is hardly any difference in height between the river-bed and the banks. Furthermore, such depositing is progressing upstream, which means that there is the possibility of the overflow point moving upstream.

(5) Sediment Production and Discharge.

Sediment is produced mainly by erosion above the 12km point. Since there is a considerable amount of volcanic material from eruptions, lahar frequently occured and caused substantial erosion of the river valleys.

(6) Important Objects to be Protected

The Mataram main irrigation channel, which provides irrigation water for an area of 15,000 ha, as well as national roads and other important facilities are located in this basin.

2. Design Basic Points

The following are design basic points for dealing with the sediment:

(1) 1st Design basic point: The point 12km from the crater as the boundary between the erosion and the deposit zones.

(2) 2nd Design basic point: The confluence point of K. Krasak to K. Progo.

3. Proposed Basic Amount of Sediment

The proposed sediment amount on which the facility plans for each are based are those which would apply if lahar were to flow down the K. Bebeng system and the K. Krasak main system under present conditions after an eruption. They are summerized in Table A-1.

(1) The Case of Lahar Flowing Down the K. Bebeng System (Fig. A-1)

a) Proposed Amount of Sediment to be Produced

- The amount of sediment that would be produced by 1-2 years of eruptions of the scale of that of 1969.
- 0 - 7km from the crater: Same amount of sediment production as in 1969.

- 7 - 12km from the crater: Either of the following two cases is possible, but Case-1 has been adopted:

[Case - 1] Lahar flow down a new flow course:

Same amount of sediment production as in 1969.

[Case - 2] Flow of lahar down the present course (K. Bebeng):

50% of the amount of sediment production in 1969.

- An amount of sediment production in the main K. Krasak equal to the amount of river-bed variation from 1976 to 1977.

b) Proposed Amount of Sediment Controlled on the River Cour

- 1st design basic point: The same amount as deposits in 1969 - 1970.
- 2nd design basic point: Since a large amount of deposits in 1969-1970 remain in this area and the same amount of deposit can not be expected again, the value for this point has been set at the average amount of sediment deposited between the 12 and 15km points in the period 1970-1976.

c) Proposed Amount of Sediment Discharge

The difference between the amount of sediment produced and the amount of sediment controlled on river course.

d) Proposed Amount of Allowable Sediment Discharge

- 1st design basic point: The allowable sediment discharge for the 2nd basic point plus the amount of sediment controlled on the river course between 1st and 2nd design basic points.
- 2nd design basic point: The amount that can be allowable for K. Progo. In the case of K. Progo a large amount of sediment discharge at one time would be harmful since it would raise the river-bed; however, there should not be any

problem if the amount of sediment discharge is averaged out over a period of time without pronounced peaks. Accordingly, the average value for the period 1969-1976 has been adopted.

e) Proposed Excessive Amount of Sediment (Amount of Sediment which has to be Coped with)

The difference between the amount of sediment discharge and the allowable sediment discharge.

(2) The Case of Lahar Flow Down the Main K. Krasak (Fig. A.2)

a) Proposed Amount of Sediment Production

- 0 - 7km :

  Same as in the case of K. Bebeng

- 7 - 12km:

  In the case of a new flow course: Same as in the case of K. Bebeng.

  In the case of the present flow course: Since the breadth of the K. Krasak main river is 100-150m wide as the result of past erosion, there will hardly be any more widening of the river even with lahar flow. The only sediment that will be produced will be that from river-bed deposits and river bank terraces. Assuming a river course of 1,025,000m^2 and an erosion depth of 2m between the 7 and 12km points, the amount of sediment production will be 2,050,000m^3.

b) Proposed amount of sediment controlled on river course:

Same as in the case of K. Bebeng.

c) Proposed amount of allowable sediment discharge:

Same as in the case of K. Bebeng.

The above results are summarized in Table A.1 and Figs. A.1 and A.2.

4. Location Plan of Sabo Facilities

(1) Sabo Facilities for Reducing Sediment Product and Controlling Sediment Discharge

a) Sabo Works to Fix the Valley Outlet (Fig. A.3)

In view of past conditions with respect to nuée ardente and lahar overflows, the 1st training levee will be provided near the 9km point from the crater, and the 2nd near the 10km point, both serving to keep the Lahar within the present river course. Additional training levees should be provided at other points where there is particular danger of overflowing.

b) Check Dams and Consolidation Dams

Check dams and consolidation dams will be provided in steps along the area of erosion (upstream of the 12km point) for prevention of such erosion. For K. Bebeng, a comparative study has been made of three cases for upstream of the 8.6km point, and in the case of the K. Krasak main river, 5 dams are planned for upstream of the 19km point.

c) Sand Pockets

Sand pockets will be provided for controlling the sediment discharge. Two locations have been considered: one, for between the 12km and 15km points and the other above the 8.4km point in conjunction with the three cases for check dams.

[Case I] Prevention of downward and lateral erosion with low step dams

i) Check Dams

Four dams (Be-D.6 ∿ Be-D.9) 7.5-12.5m in height are to be planned in steps above the 8.6km point.

ii) Sand Pockets

The sand pockets between the 12 and 15km points are to be reinforced and improved with provision of 3 consolidation dams and gabions to ensure that the deposits in the sand pockets are well dispersed by leveling.

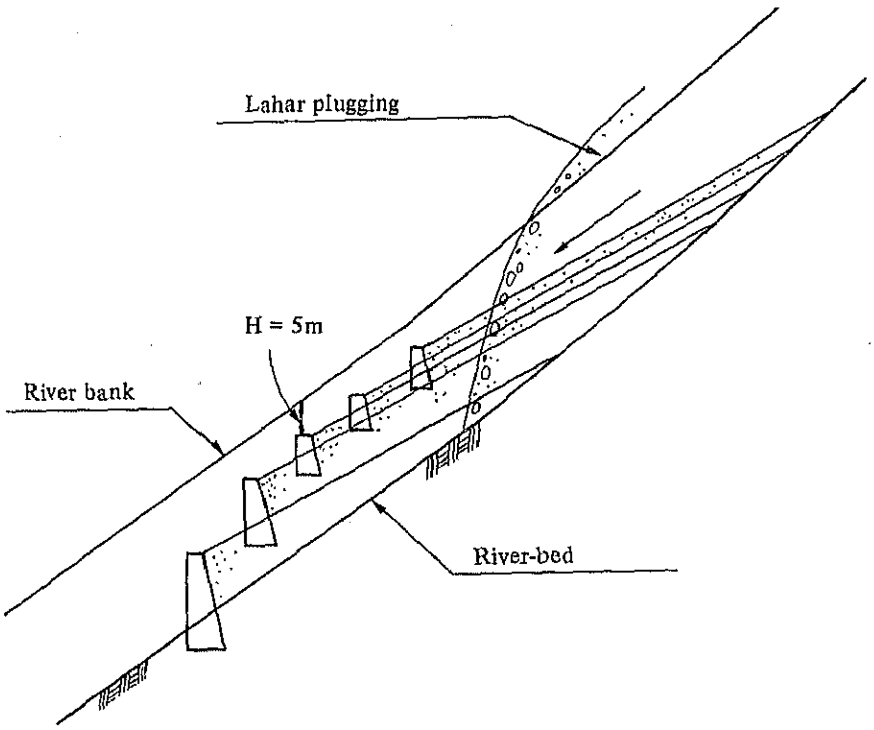
[Case II] Prevention of downward and lateral erosion by Means of increasing riverbed

i) Check Dams

Construction of a dam with a height of 9m on the deposit area of the Be-D.6 dam at the 8.6km point after deposition. Provision of three other dams increasing heights to raise the river-bed as high as possible (but not to the extent that there would be lahar overflow) and about 5m below the river bank. The aim is to prevent erosion subsequent to possible stoppage of the valley by Lahar.

ii) Sand Pockets: Same as in Case I.

Illustration of Case-II: increasing river-bed with check dams.



[Case III] Dispersal of Lahar

Raising of the river-bed in the upper lsope area to the level of the bank in order to disperse the lahar,

i) Check Dams

Constructing of 4 dams (Be-D.6A ∿ Be-D.6D) in a line, each on the deposit of preceding one, until the river-bed is brought up to the level of the bank.

Furthermore, the lahar overflow will be directed into the present river course by means of training levees.

ii) Sand Pockets

- 1,000,000m^3 of sediment will be controlled on the area of 500,000m^2 above the Be-D.6 dams.
- As for the remaining amount, it will be controlled with sand pockets between the 12 and 15km points, as in Case I and Case II.

(2) River Course Improvement Facilities

a) Between 15 and 20km points (from the confluence points of K. Krasak and K. Bebeng to a point about 3km below the national road)

i) Provision of embankments and revetment at points where there is risk of overflow.

ii) Improvement of the channel line of the bend near the national road bridge.

b) Between the 20km and 24km points (from the point about 3km below the national road to the entrance of narrow channel)

Beginning from the 20km point, which is about 3km downstream from the national road, the stream gradient drops and the river widens, drastically reducing bed load capacity and sharply increasing deposits, and from the 24km point to the point where the river flows into K. Progo the breadth of the river is a narrow 40-50m, and the river-bed gradient is steep. Furthermore, there is an unused weir at the 26km point that is a bottleneck for sediment flow. In this section the sediment should be sent promptly into K. Progo rather than be allowed to deposit.

i) Lowering the Height of Weir

Bed load capacity is to be increased by lowering height of weir about 3m, by lowering the river-bed, and by increasing the stream gradient. This will entail protective works (consolidation dam) for the siphoning of the Mataram irrigation channel that crosses the river and for the protection works hear the bridge.

ii) Reduction of River width and Fixation of Low Water Channel

Embankments and revetments will be provided for a river width of about 100m. A low water channel of about 40m will be fixed by means of a groin for lowering the designed river-bed by about 2m.

The order of scheduling the work will be as follows:
(a) lowering the crown of the weir
(b) temporary works, and
(c) permanent works (see Fig. A-4).

Since it is considered necessary to undertake works for the prevention of overflow prior to the completion of reducing works for sediment upstream, temporary works will be undertaken to fix the channel, leaving the works proper for a later stage when the river course has been stabilized.

- In order to cope with variation in the river-bed, flexible construction methods and simple and inexpensive facilities are to be used. Bamboo gabion, wooden or bamboo groin, skelton work, etc. are some of the possibilities in this regard.
- In order to be able to cope with unforessen changes in the river regime and in the main works as well, it

will be necessary to stabilize the present river course as it is. Furthermore, the entire surface of the dike is to be protected with revetment of wet masonry to prevent damage in the event of overflow.

iii) Between the 24km and 26km points (from the neck to Blaburan Bridge)revetments are to be provided for the protection of the Mataram irrigation channel and other objects.

(3) Sediment Disposal Plan

Two Lahar flow directions are considered at a major eruption as follows:

i) flowing down the K. Bebeng system and
ii) flowing down the K. Krasak system.

For safety in either case, the plan will take into account separately the needs of each in terms handling the amount of sediment discharge at 1st design basic point.

The sediment disposal plan are decided as follows:

a) The amounts of sediment product to be recuded and discharge are assumed.

b) The amounts of discharge are decided as the amount to be controlled at sand pocket. It the amounts of sediment discharge are differ between K. Bebeng and K. Krasak, the larger amount will be decided as the propose amount of sediment to be controlled at the sand pocket.

The proposed amounts of sediment disposal are shows in Table A-2.

(4) Construction Cost Estimates

The construction cost are estimated on the unit costs of 1978.

(5) Determination of Draft Plan

By a comparative study of the three cases, Case I having been selected because of its superiority in terms of safety and low construction costs.

The Sabo facilities and locations planned and the construction cost estimates are summarized in Tables A.2 and A.3, and detailed in Appendices 3 and 4.

Table A.3 Summary of Sabo Facilities on K. Krasak

Unit: Rp. 1,000

Check dam	Consolida-tion dam	Training levee	Dike and revetment	groin	Others	Construction cost extimates
14	10	(m) 7,140	(m) 22,200	(m) 4,500	Lowering the crown of weir	7,300,000

Table A.1 Proposed Sediment Amount on K. Krasak

Unit: $10^3 m^3$

Mark	Proposed Sediment Amount	1st Design Basic Point		2nd Design Basic Point	
		Mark	Sediment Amount	Mark	Sediment Amount
a	Amount of sediment production	a_1	11,804	a_2	0
b	Amount of sediment controlled on river course	b_1	2,449	b_2	75
c	Amount of sediment discharge	c_1	$(a_1 - b_1)$ 9,355	c_2	$(c_1+a_2-b_2)$ 9,280
d	Allowable sediment discharge	d_1	1,275	d_2	1,200
e	Excess sediment	e_1	$(c_1 - d_1)$ 8,080	e_2	$(c_2 - d_2)$ 8,080

Fig. A.1 Relation between Forms of Sediment Load and Rates of Flow at Blaburan
(Shinohara - Tsubaki formula)

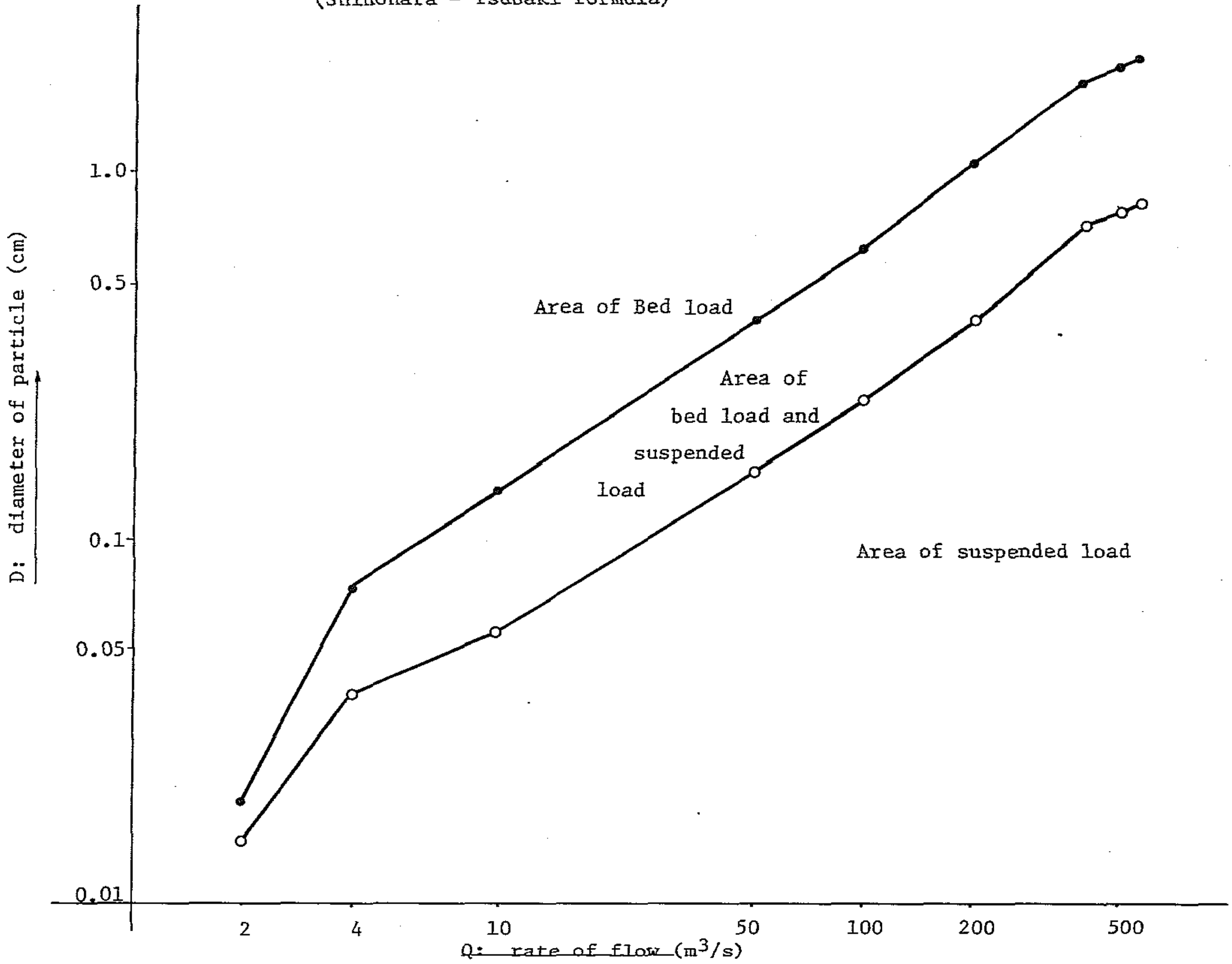
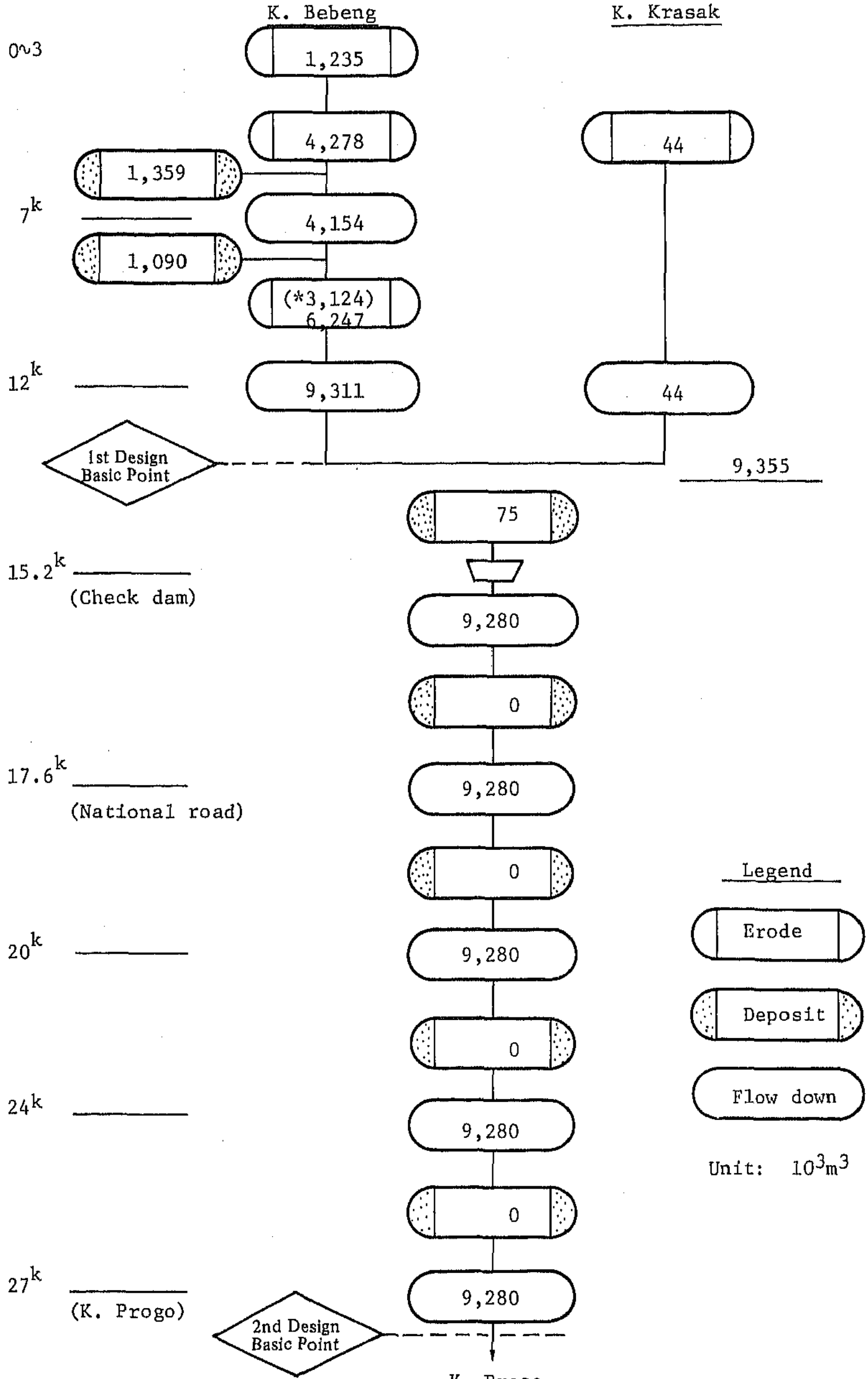


Fig. A.1 Balance of Sediment Production and Discharge along K. Krasak (Proposed sediment amount)

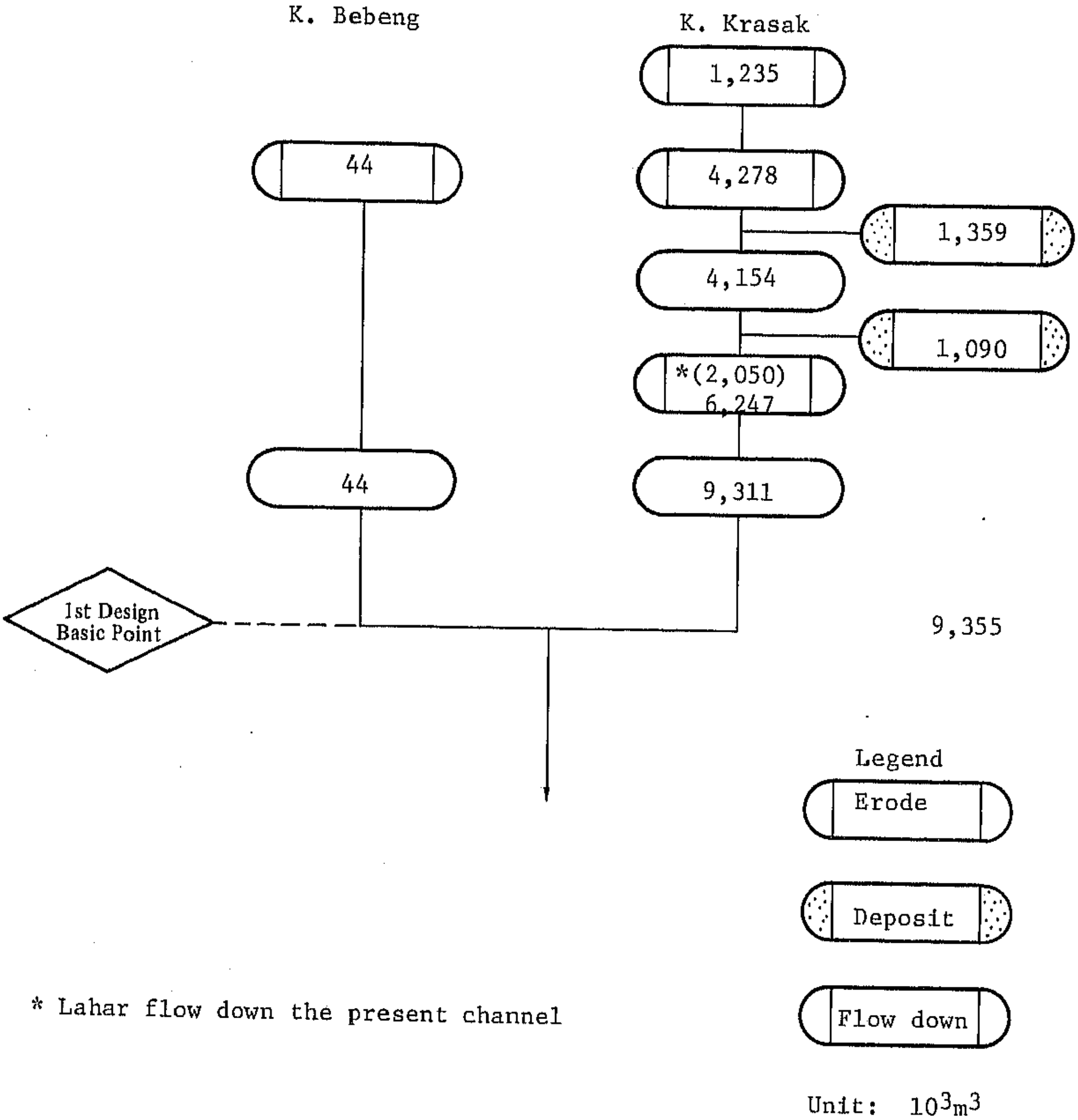
Condition: Lahar flow down the K. Bebeng system



* Lahar flow down the present channel

Fig. A.2 Balance of Sediment Production and Discharge along K. Krasak

Condition: Lahar flow down the K. Krasak main river



* Lahar flow down the present channel

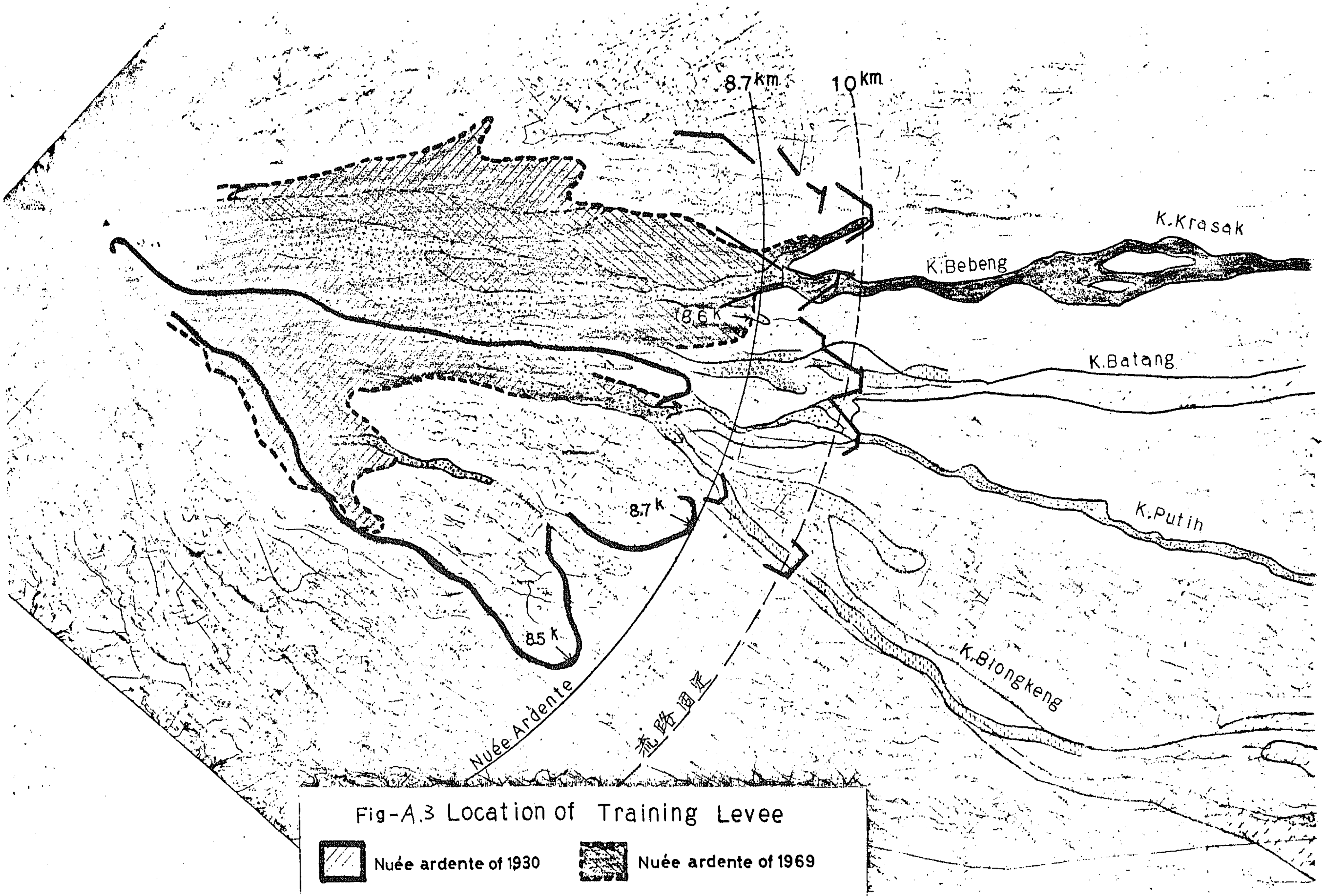


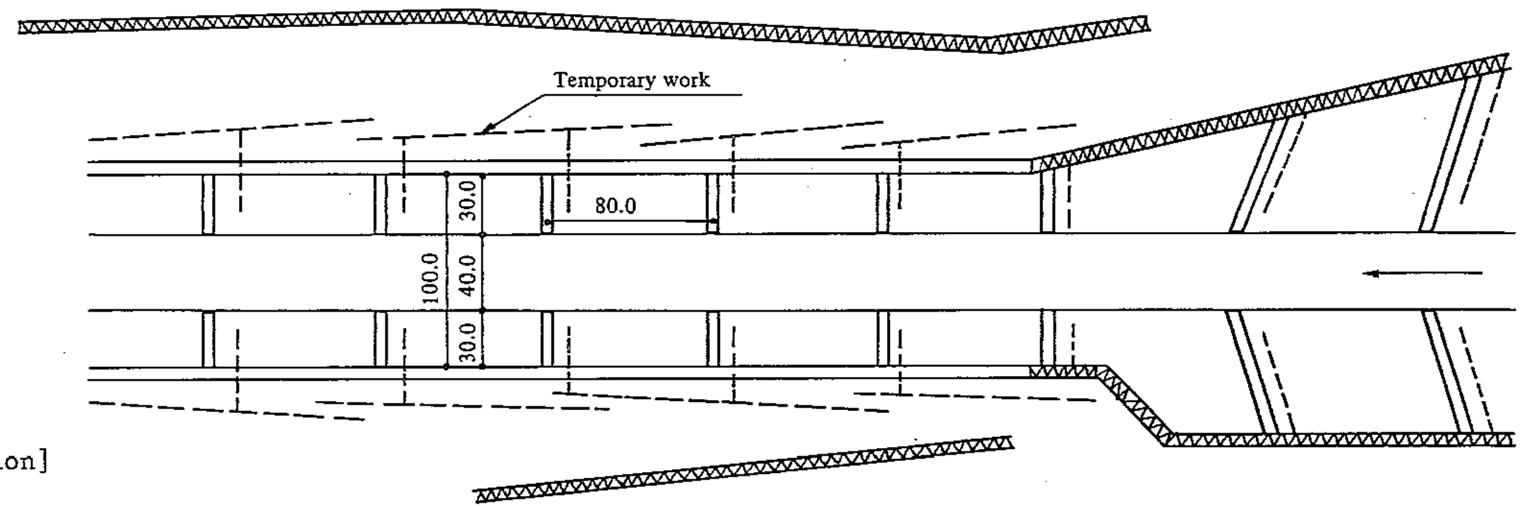
Fig-A.3 Location of Training Levee

Nuée ardente of 1930 | Nuée ardente of 1969

Lahar deposit of 〃 | Lahar depsit of 〃

Fig. A-4 River Course Improvement Plan (between 20km and 24km)

[Location]



[Cross Section]

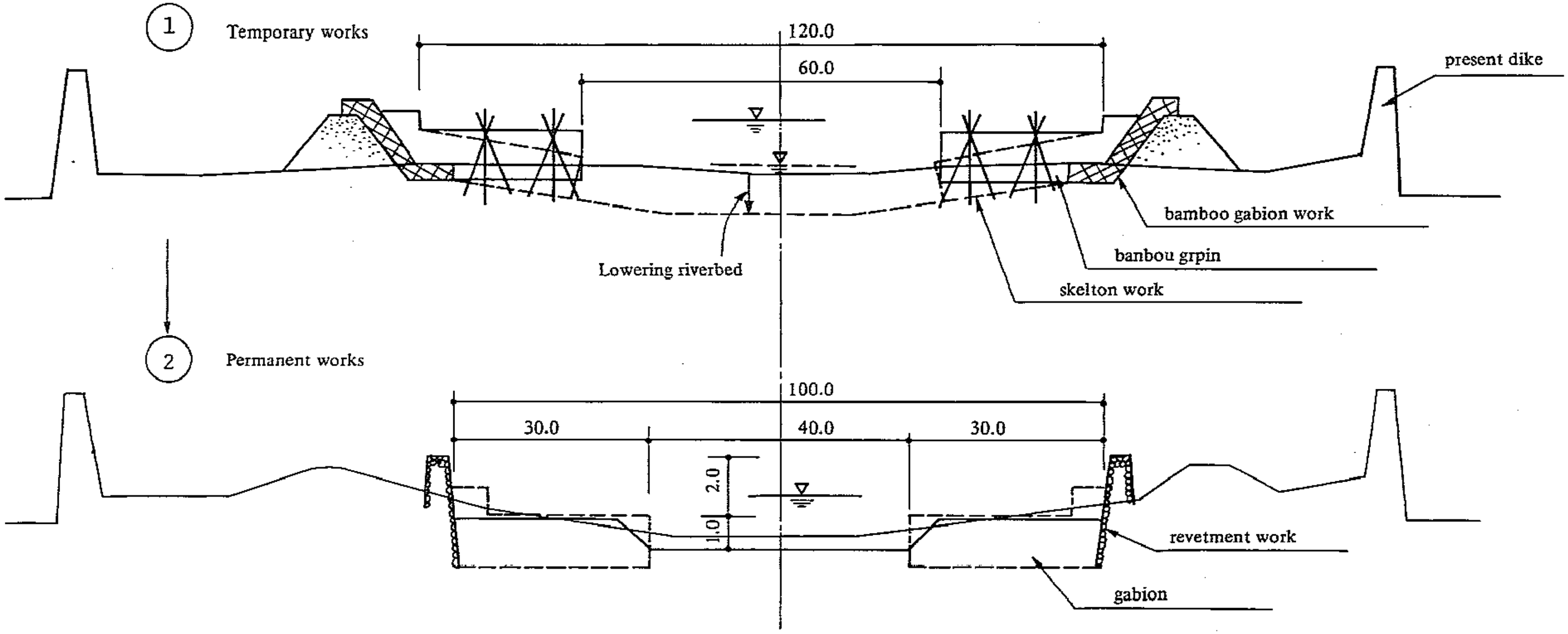


Table A.2 Proposed Sediment Amount of Along K. Krasak

Unit: 10^3 m^3

		Case-1		Case-II		Case-III		Remarks
			Amount		Amount		Amount	
Excess amount of sediment			8,080		8,080		8,080	
Reduction amount of sediment	Fixing valley outlet	(1) 1	(4,197) 3,123	1	3,123	1	3,123	
	Check dams and consolidation dams	(5) 15	(729) 1,958	16	2,207	15	2,332	
	Subtotal	(6) 16	(4,926) 5,081	17	5,330	16	5,455	
Amount of sediment to be controlled	Sand pocket	(1) 1	(3,154) 2,999	1	2,750	2	1,000 1,625	
	Depth		(1.8m)		1.6 m	8.4 km 12~15km	2 m 0.9 m	
	Total	(1)	(3,154) 2,999	1 1	2,750	2	2,625	
Total		(7) 17	(8,080) 8,080	18	8,080	18	8,080	

B. TYPE-II K. WORO
Sabo Facilities Location Plan

1. Characteristics of the Basin

(1) Dimensions

- Basin 42.1km^2
- Stream length: 27.2km
- Mean stream gradient: 8.7 %
- Design flood discharge: 590 m^3/s

(2) Influence of Volcanic Eruptions

There will be little influence from valcanic eruptions, with only some mud flow of valcanic ash at the upper area above 2,000m.

(3) Form of Sediment Transportation

- Nuée ardente area: upper stream of 11km (EL.550m) from the top
- Lahar area: upper stream of 16km (EL.360m)
- Erosion area: upper stream of 10km (EL.650m)

(4) Sediment Production and Discharge

Sediment production and discharge takes place principally within 10km of the crater. Most of the deposits is from past lahar deposits, including many terrace deposits. Lahar occurs with a heavy rain, but usually there is not much sediment product and discharge.

(5) Sedimentation

Since the stream gradient of the main river, K. Dengkeng, is low and the sediment flow capacity is very small, sediment supplied from upstream is deposited in the lower slope area, forming an alluvial fan-like area. Sand pockets and dikes have been common for a long time downstream for the sake of preserving farmland.
The river-bed is far higher than the land side.

(6) River-bed Variation and Overflowing

The river-bed of K. Denkeng has at times risen by the sedimentation as high as 2.0m in recent years and it usually took several years to lower itself to the previous level.

The river-bed of K. Woro has risen almost to the same level as the banks at 11km from the crater, and it has become gradually higher than the land side downstream there. For this reason, there has long been frequent overflowings in the area of alluvial fan.

(7) River-bed Materials

90% of the river-bed materials consist of particles below 2.0mm.

2. Design Basic Points

The following are design basic points for dealing with the sediment:

(1) 1st design basic point: 10km from the crater

(2) 2nd design basic point: Confluence point with K. Dengkeng

3. Proposed Basic Amount of Sediment

Because the sediment discharge capacity to K. Denkeng is very small, both the sediment amount that causes damage during a big flood and the amount of sediment discharged in ordinary year must be controlled. The amounts are summerized in Table B-2 and explained as follows:

(1) Flood year (one-year periods in which design flood occurs)

a) Proposed Amount of Sediment to be Produced

Sediment production in years of a major flooding from unstable deposits susceptible to erosion.

4,219,000 m^3/year

b) Proposed Amount of Sediment Controlled on Channel

1st design basic point:

From the survey of the traces of past floods, the amount of sediment to be controlled has estimated as a thickness of 2-3m. The sediment controll depth of 2.0m is adopted.

River-bed area of $244,000m^2$ x 2m = $488,000m^3$
(12% of amount of sediment production)

2nd design basic point:
Not considered of the sediment amount to be controlled.

c) Proposed Amount of Sediment Discharge

1st design basic point:

$3,731,000m^3$
($4,219,000m^3$ - $488,000m^3$)

2nd design basic point:
$3,731,000m^3$
($3,731,000m^3$ - 0)

d) Proposed Allowable Amounts of Sediment Discharge

1st design basic point:

Considering the sediment discharge of $8,600,000m^3$/year in 1975 as calculated by the Brown formula on the largest discharge at the confluence point with K. Denkent since 1969. The amount is to be $8,000,000m^3$/year.

2nd design basic point:

Same as for 1st design basic point.

e) Proposed Excess Amount of Sediment Discharge

1st and 2nd design basic points:

$3,723,000m^3$/year (amount of sediment discharge minus the amount of allowable sediment discharge).

(2) Ordinary Years

The stream gradient of K. Woro in the vicinity of the confluence point with K. Denkeng is as small as 1/600 and hence the sediment flow capacity is small as only 4,000-8,000m^3/year. Consequently, the river-bed has become higher than the land side, which causes floods. For this reason the amount of sediment discharge in ordinary years must be considered as well as the amount in a year of major flooding.

The sediment deposited in sand pockets in a flood year has been carried downstream a little at a time. The question whether or not this amount of sediment discharge in ordinary years will be harmful to the downstream areas, was studied.

a) Proposed Amount of Sediment Discharge in Ordinary Years

This amount is assumed to be 44,000 m^3/year considering the average sediment discharge per square kilometer for K. Krasak in 1976-77.

At K. Woro sand pocket outlet point:

$12.8km^2 \times 3,413m^3/year = 44,000m^3/year$

b) Proposed Allowable Sediment Discharge

The amount is assumed to be 4,000m^3/year as based on the calculations of the amount of sediment discharge in 1969-76 at the confluence point with K. Dengkeng.

c) Proposed Excess Amount of Sediment Discharge:

The amount is assumed to be 40,000m^3/year or (a) - (b) .

This amount means that without countermeasures, every year the amount of 40,000m^3 will be deposited and raise the river-bed downstream of the sand pocket bit by bit.

4. Sabo Facilities Location Plan for

The sabo facilities will be provided in such a way as to make it possible to cope with the excess amount of sediment both in flood years and in ordinary years. The amounts are:

- The proposed excess amount of sediment discharge in a flood year:

  3,723,000 m^3/year

- The proposed excess amount of sediment discharge in an ordinary year:

  40,000 m^3/year

(1) Facilities for Reducing Sediment Production

In order to reduce the erosion of river-bed and flood terraces, two consolidation dams and 9 check dams in step are planned.

(2) Facilities for Controlling of Sediment Discharge

For the purpose of controlling the amount of sediment discharge, improvement of the existing sand pockets, check dams and three new consolidation dams are planned.

(3) Improvement of River Course

Improvement of dike and revetment are planned.

They are summerized in Table B-3.

(4) Countermeasures for the Excess Amount of Sediment in Ordinary Years

[Case I] Excavation of deposits on check dams and sand pockets.

In order to control the sediment amount, excavation of the deposits at the check dam will be planned. The sand removed from the check dam will be dumped behind the dikes to reinfore them, and the excavated area will be used for a reservoir. Also some amount of the deposit will be available for use as construction materials.

- The amount of deposits excavated will be as follows:

For construction materials:	10,000 m^3/year
For excavation:	30,000 "
Total:	40,000 "

The total amount of deposits that will be excavated in 50 years of project life estimated comes to 1,500,000m^3 (30,000m^3/year x 50 years) and the cost for exavation will be divided as follows:

- By construction cost:

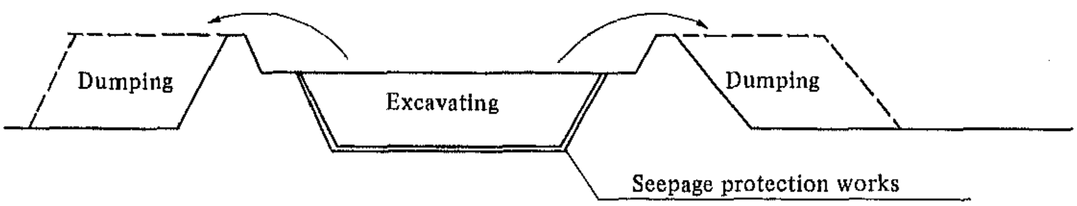
  750,000m^3
  - 450,000m^3 .... Excavation for the improvement works
  - 300,000m^3 .... Excavation for the maintenance during construction period

- By maintenance cost:

  750,000m^3 .... Excavation for the maintanance works after the construction period

- The areas of excavating and dumping

  The deposits excavated will be dumped behind the dikes upstream of the check dam. The excavation area will be 450m in length, 200m in width, and 5m in depth.



- The usage of excavated area:

  In fifteen years 450,000m^3 of deposits will be removed, and the excavated area will be used as a reservoir after construction of seepage protection works. Furthermore, after constructing the reservoir, amount of yearly sediment should be excavated for 25 years, and the excavating cost should be included in the construction cost.

- The usage of dumping areas

  The area will be used for agricultural land by improving surface soil.

[Case II] Sand pockets

Provision of new sand pocket in the downstream area of K. Woro.

- Planned volume:

  30,000m^3/year x 50 years = 1,500,000m^3

- Structure:

  Enclosing the area (50ha) with dikes, the design depth of deposits will be 3m. In order to use the sand pocket area as farmland, the 50ha area will be divided into five sand pockets by internal partition dikes and they will be used for depositing one at a time.

[Case III] Height increase of dikes

Increasing the hight of dikes between the check dam and the sand pocket so as to be able to deposit the amount of sediment discharged over fifty years.

- Planned Volume:

  30,000m^3/year x 50 years = 1,500,000m^3

- Structure

  Increasing the height of dike:

  2.9m (1,500,000m^3/510,000m^2)

  Total length of levees:

  12,000m

The sabo facility location plan and construction cost estimates are summarized in Tables B-3 and B.4 and showed in detail in Appendices 3 and 4 as based on the above policies.

For dealing with the excess amount of sediment in ordinary years, case-I was adopted as being the safest and most economical of the three cases considered.

Table B.1 The Amount of Sediment Discharge During 1976 and 1977 from River-Bed Variation Survey Areas

Tributaries	Basin (kg. km)	Sediment discharge (cu. m/year)	Sediment discharge per sq.km (cu.m/year, sq.km)	Remarks
	km^2	m^3/year	$m^3/year/km^2$	
K. Krasak	23.0	37,700	1,639	The confluence point of K. Bebeng and K. Krasak
K. Bebeng	9.4	106,000	11,277	"
K. Putih	25.8	16,400	636	National road
K. Blongkong	71.2	52,000	730	The river month of K. Blongkeng
K. Batang	22.8	63,500	2,785	"
Average			3,413	

Table B.2 K. Woro Proposed Amount of Sediment

Unit: 10^3(cu.m/year)

Mark	Sediment	1st Design Basic Point		2nd Design Basic Point	
		Mark	Amount	Mark	Amount
a	Amount of Sediment product	a_1	4,219	a_2	0
b	Amount of sediment controlled on channel	b_1	488	b_2	0
c	Amount of sediment discharge	c_1	3,731 (a_1 - b1)	c_2	3,731(44*) ($C_1 + a_2 - b_2$) 3,729
d	Allowable sediment amount	d_1	8	d_2	8 (4*)
e	Excess amount or sediment discharge	e_1	3,723 ($C_1 - d_1$)	e_2	3,723(40*) ($C_2 - d_2$)

* Figures are the amounts of ordinary year

Table B-3 Proposed Sabo Facilities and Sediment Amont

(Unit: 10^3 m^3/year)

		Flood year		Ordinary year		Remarks
		Number	Sediment amount (m^3)	Number	Sediment amount (m^3)	
Excess amount of sediment			3,723		40	
Reduction amount of sediment	Check dams and consolidation dams	12	1,737			
				1	*40	
	Sub total	12	1,737	1	*40	
Amount of sediment to be controlled	Sand pocket	2	1,986			Include the check dam upstream of the national road and three consolidation dams
	Depth		0.58 m			
	Sub total		1,986			
	Total		3,723		40	

* Reduction amount of sediment discharge

Table B.4 Summary of Sabo Facilities on K. Woro

Unit: Rp. 1,000)

Check dam	Consolida-tion dam	Training levee	Dike and revetment	Groin	Others	Construction cost estimate
		(m)	(m)	(m)		(m)
10	5	-	11,520	3,000	Excava-tion work	4,500,000

C. TYPE-III K. BOYONG
Sabo Facilities Location Plan

1. Characteristics of the Basin

(1) Dimensions

Basin:	76.0km^2
Stream length:	37.0km
Mean stream gradient:	8.0%
Design flood discharge:	695m^3/s

(2) Influence of Volcanic Eruptions:

Hardly any at present.

(3) Areas and Forms of Sediment Transportation

Nuée ardente area:	upper stream of 10km (EL, 650m) from the top
Lahar area:	upper stream of 15km (EL, 420m)
Erosion area:	upper stream of 13km (EL, 470m)

(4) Sediment Production and Discharge

- Erosion occurs on the river cause between the 5km and 13km from the crater.
- Past lahar deposits are the source of sediment production, and comparatively a large amount of unsound river-bed deposits exist.
- Although lahar could occur during major flooding, in ordinary years there will be little sediment discharge.

(5) Deposits:

Particularly large amounts oxisting between the 8km and 12km points.

(6) Composition of River-bed Materials

As a result of outflow of fine particles, the remaining deposits consists of relatively large grains.

(7) Irregular Flow and Lateral Erosion

Past sediment discharge has been left large grains in the form of sand bars, resulting in irregular flows and causing lateral erosion.

(8) River-bed Variation and Overflowing

The amounts of sediment discharge are rather little in ordinary years and the river-bed has been lowered. The causes of overflowing are mainly irregular flows and bottlenecks at bridges.

2. Design Basic Points

(1) 1st design basic point: 13km point from the crater

(2) 2nd design basic point: national road bridge

(3) 3rd design basic point: confluence point with K. Opak

3. Proposed Amount of Sediment

(1) Proposed Amount of Sediment to be Produced

The amount of sediment to be produced in a major flooding year from unstable deposits.

At 1st design basic point:
1,437,000 m^3/year

(2) Proposed Amount of Sediment to be Controlled on the Channel

	Design Basic Points		
	1st	2nd	3rd
. Area of channel (m^2)	229	723	252
. Depth of deposits to be controlled (m)	2.5	0	0
. Amount of sediment to be controlled (m^3)	573	0	0

(3) Proposed Amount of Sediment Discharge:

Design basic points	Amount (m^3)
1st	864 (1,473 - 573)
2nd	864 (864 - 0)
3rd	864 (864 - 0)

(4) Proposed Allowable Amounts of Sediment Discharge

In 1976-77 the amount of sediment discharge due to river-bed variation in K. Krasak and the other five rivers was 3,413 m^3/km^2 year. Since the allowable sediment discharge sought here is that for the year of major flooding, this figure has been multiplied by the ratio (2.1) of the value for 1975, the largest in recent years, to the value for 1976, as calculated on the basis of the Brown formula.

The value is 7,167 m^3/km^2/year (= 3,413 m^3/km^2/year x 2.1)

Design Basic points	Basin Area	Allowable sediment discharge amount
1st	11.4 (km^2)	80 (m^3)
2nd	50.4	360
3rd	76.0	540

(5) Proposed Excess Amount of Sediment Discharge:

The amount is assumed to be 784m^3.

Design Basic Points	Amount of Sediment Discharge	Allowable Sediment Discharge	Excess Amount of Sediment Discharge
1st	864(m^3)	80 (m^3)	784 (m^3)
2nd	864	360	504
3rd	864	540	324

4. Sabo Facilities Location Plan

The Sabo facilities will be provided in such a way as to be able to cope with the 784,000m^3 of excess amount of sediment discharge at the 1st design basic point.

(1) For Reducing the Amount of Sediment to be Produced

Five check dams will be provided to prevent erosion of the river-bed and banks between the 8km and 13km points.

(2) For Controlling the Amount of Sediment Discharge

The sediment discharge will be controlled by controlling effects of check dams. Since there is expected only small amount of sediment discharge over a long period in the case of K. Boyong, it should be possible to restore the sediment discharge controlling function by the time of coming flood by reducing the accumulated deposits above check dams by sharp stream gradient at the time of flooding, and by gradual flowing out thereafter.

Flood deposit river-bed gradient: 3/4 of I
Ordinary deposit gradient: 1/2 of I
"I" is the original river-bed gradient.

(3) For River Course Improvement

a) Consolidation dams and revetment works will be planned for the points where there will be dangers of overflowing and places where the bank will collapse.

b) Bridges that are bottlenecks and overflowing points will be relaid.

c) The plan will ensure that the river-bed must be maintained its present level in view of the fact that there is frequent flooding of residential areas along the channel in the enter of Kota, Yogyakarta. From environmental points of view consideration will also have to be given to the scenic effects of the river course, since it flows through the center of the city that is one of the most important tourism centers of Indonesia.

The details of plan are summarized in Table C.1 and C.2, and C.3 and showed in detail in Appendices 3 and 4.

Table C-1 K. Boyong Proposed Amount of Sediment

Unit: 10^3 m^3/year

Mark	Proposed Sediment Amount	1st Design Basic Points		2nd Design Basic Points		3rd Design Basic Points	
		Mark	Amount	Mark	Amount	Mark	Amount
a	Amount of Sediment	a_1	1,437	a_2	0	a_3	0
b	Amount of sediment to be controlled on channel	b_1	573	b_2	0	b_3	0
c	Amount of sediment discharge	c_1	$(a_1 - b_1)$ 864	C_2	$(c_1+a_2-b_2)$ 864	c_3	$(c_2+a_3-b_3)$ 864
d	Allowable sediment amount	d_1	80	d_2	360	d_3	540
e	Excess amount of sediment discharge	e_1	$(c_1 - d_1)$ 784	e_2	$(c_2 - d_2)$ 504	e_3	$(c_3 - d_3)$ 324

Table C.2 Summary of Sabo Facilities on K. Boyong

Unit: Rp. 1,000

Check dam	Consolidation dam	Training levee	Dike and revetment	Groin	Others	Construction cost estimates
(m) 5	(m) 2	-	(m) 6,960	-	* 2	(RP) 1,500,000

* Bridge

Table C.3 Proposed Sabo Facilities and Sediment Amount

Unit: 10^3 m^3/year

		Number	Amount
Excess amount of sediment		-	784 (m^3)
Reduction amount of sediment	Check dam	5	515
Amount of sediment to be controlled	Check dam	(5)	269
Total		5	784

3.3 Countermeasures in River Trouble Spots

River disasters in the area consist primarily of flood inundation and functional distuption of irrigation intake. The follow is the basic policy for disaster prevention.

(1) Control of Sediment Discharge

K. Progo is very much affected by sediment discharge during flooding. As revealed by the record of river-bed changes, there has been considerable sediment discharge. An estimated 7 million cubic meters of sediment was deposited between the confluence point of K. Krasak and the river mouth in 1969 as a result of the eruption of G. Merapi and the rise in water in the rainy season.

The basic principle in the prevention of river disasters is maintenance of river-bed stability. Accordingly, it is of primary importance to keep down the sediment discharge through upstream disaster prevention measures. At the same time, it is necessary to take measures to maximize the river course's sediment flow capacity.

The hydrology and hydrography team has calculated that the sediment flow capacity in the downstream area at Srandakan Bridge is 3,000 cubic meters a year or 1/5 that at the Duet gauging station upstream. The stream gradient is 1/600 on practically a straight line between the river mouth and Duet. For the sake of increasing the amount of discharge between those two points, an appropriate HWL will be achieved by reducing the bread of the river course downstream, (which is presently 500 - 700m as compared to about 100m upstream) and by dredging or excavating the river-bed.

(2) Stabilization of Meandering

Both K. Progo and K. Opak have precipitous alluvial fan-like river courses. K. Progo in particular has a wide breadth in the downstream area, where its winding is of a plural and forced nature. This makes for very low stability of the main flow line during flooding and lack of stability of corner winding as well. There is danger of side erosion all along the river course and loss of valuable land. What must be done, therefore, is to narrow the river breadth somewhat, achieve a single winding pattern for greater winding stability, and protect the river bank at the corners of winding.

(3) Construction of Training Levees at River Mouths

In the case of both K. Progo and K. Opak, there is no extention of the river mouth in the east-west direction. In the dry season the river mouth is almost completely closed. This phenomenon is the result of a large amount of sediment discharge that comes to the river mouth during the rainly season as well as a decline in the volume of discharge capacity in the dry season and a change in the wind direction from east to west creating strong drift currents. River mouth closing is a general phenomenon for rivers that flow into the Indian Ocean, but very rarely occurs for rivers that flow into Java sea since the seabed is shallow and allows for extension of the river mouth.

The construction of training levees would seem to be an effective measure for improvement of the river mouth and mitigation of damage (inland water inundation) behind the levee in the downstream area.

(4) Proposed River Bed Improvements

A channel improvement plan for the K. Progo has been proposed. The plan may have to be rough as it is prepared from the extremely limited available longitudinal and cross levelling, and plane map survey data. The most urgent and important matter is to determine river channel survey data as completely as is practically possible.

a) The downstream channel cross sections should be large enough to take care of sediment from upstream and stabilize the river-bed.

b) The proposed river improvements are limited to the section between the estuary to a point about 20km upstream.