3.3 SEDIMENT BALANCE OF LAHAR OF 1981

(1) Outline

Sediment balance calculations were performed for the basin based upon the volume of erosion and of the accumulation caused by the lahar of May, 1981, and obtained as discussed in the foregoing sections, i.e., 3.1. and 3.2.

In general, sediment balance calculations are performed by totaling the volume of change in the amount of earth observed at all sections lying from the downstream or upstream end of the basin. Since the volume of earth that flowed out into the sea is not known for the basin under discussion, calculations were performed starting at the upstream end.

(2) Estimation of Produced Volume of Sediment Caused by Lahar

With regard to the topographical conditions and the route of transport of the lahar of May, 1981, the sections and the form of occurrence as regards the lahar were listed as follows and examination was made on the items which had not been calculated in the foregoing sections i.e.) landslides on the valley wall, ii) lateral erosion and iii) river bed dissection.

Table-3.6 Classification of Form and Place of Produced Sediment

Form of Occurrence	Place of Occurrence	Form of Occurrence	Place of Occurrence
Collapse	Mountainside	Valley wall collapse	Valley wall (slope under attack)
Slope erosion	Slope surface layer	Lateral erosion	Old terrace
Upper valley wall erosion	Upper valley wall	River bed erosion	River bed

(i) Landslide on the Valley Wall

In the valley section, the materials of the valley walls are relatively loose, therefore, valley wall failure occurred on these walls during or just after the passing of the lahar. In view of this, valley wall failure, average in scale, confirmed through the interpretation of aerial photographs and field investigations are assumed to have occurred on the undercut slopes of each river

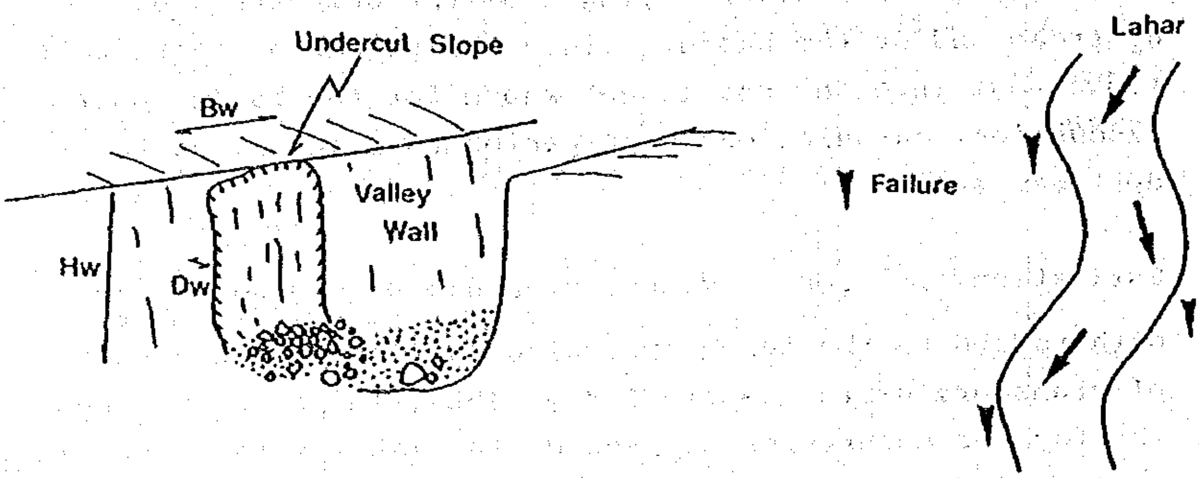


Fig.-3.2 Concept of Valley Wall Failure

during or after the flowdown of the lahar. The volume of debris produced on this valley wall was assumed to be identical to that obtained by the following formula:

Valley wall relative height (Hw) x Width (Bw) x Depth (Dw)

The value obtained by the formula was multiplied further by the number of the slopes subject to attack (Nw) for each valley. As an equation to represent a typical scale of degradation, Bw = 20 m and Dw = 1 m were adopted.

(ii) Lateral Erosion

Excavation of the old terraces and the bottom sections inside the channel is considered to have occurred as a result of the lateral eroding force of lahar. Since estimation of the volume of such erosion is very difficult, the volume of lateral erosion was included in that calculated for old terraces inside the valley. The volume of side erosion obtained was used for sections where the presence of old terraces could be confirmed. The erosion thickness was assumed to be 3 m (See Fig.-3.4).

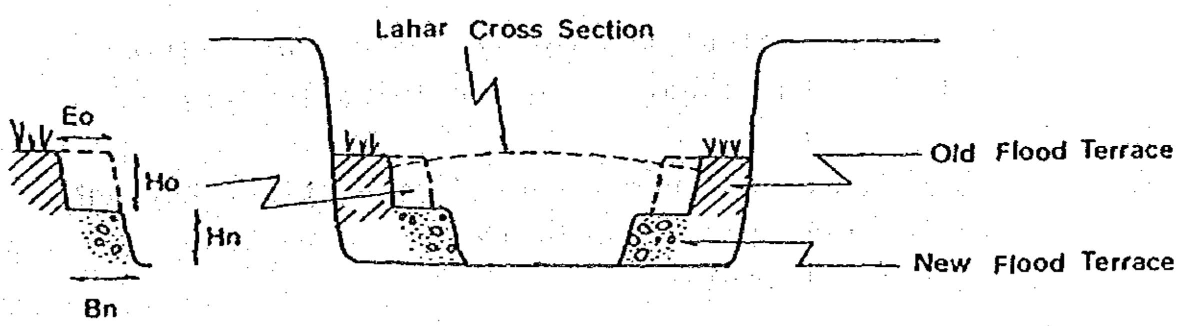


Fig.-3.3 Concept of Lateral Erosion of Old Terrace on the Valley Bottom

Old terrace relative height (Ho) x Old terrace length (extension) (Lo) x Erosion thckness (Eo)

Although the presence of the volume of lateral erosion with regard to valley walls and channels inside fans can be considered, it was excluded since an estimation proved difficult. The volume was assumed to have been taken care of by the slight increase in the volume of failure on the valley wall and river bed dissection.

(iii) River Bed Dissection

Several sections are considered to have been subjected to river bed erosion,inside the valley and on the river bed at the top of the fan. Here, for each applicable section, a value obtained by the following formula was given. The depth of erosion, however, was estimated for each section based upon the results of field investigations and inquiries.

Valley bed width (Bc) x Channel length (Lc) x Dissected depth (Dc)

The values calculated for the volume of sediment caused by the lahar are given in Table-3.3.

The sediment balance expected at sections through which a valley run can be expressed by the following formula:

$$V_4 = V_1 + V_2 - V_3$$

Where,

V_1 : Volume of sediment flowing into the applicable section form the upper basin

V_2 : Volume of sediment occurring at the applicable section

V_3 : Volume of sediment accumulated at the applicable section

V_4 : Volume of sediment flowing out from the applicable section

A series of calculations performed, beginning at the upper basin, by the above formula enables comprehension of the outline of the volume of sediment transported within the basin. The results of calculations made for sediment balance in such a manner are shown in Table-3.4 and Fig.-3.5. It should be noted, however, that the volume (y) of lahar flowing in from the main B. Sat inside the K. Mujur basin was assumed to be 0.

According to the results of these calculations, the volume of flow into each fan and that into the sea are as follows:

Table-3.7 Result of Sediment Balance

	K. Rejali	K. Mujur
Volume of flow into fan	1235.6	1297.5 + y
Volume of flow into sea	270.9	21.7 + y

y: from B. Sat frunk river

Table-3.8 Estimated Sediment Volume of Products in K. Rejali Basin

			Gully Wall Failure			Lateral Erosion			Downward Erosion				Total
	Elevation m	Length km	HW m	NW	Volume x 1000m³	Ho m	Lo km	Volume x 1000m³	Lc km	Bc m	Dc m	Volume x 1000m³	Volume x 1000m³
Curah Lengkong	3000												
	2000	5.2	20	26	10.4				5.2	30	3	468	478.4
	1000	2.3	30	8	4.8	2	3.6	21.6	2.3	40	1	92	118.4
Kobo'an Conf.	820	1.4											
Subtotal	720			34	15.2			21.6				560	596.8
3 . Kobo'an	2000	5.3	30	12	7.2				5.3	30	1	259	266.2
	1000	2.3	30	4	2.4	3	3.1	27.9	2.3	30	1	69	99.3
Curah Lengkong Conf.	820	1.4	30	2	1.2	3	2.4	21.6	1.4	40	0.5	28	50.8
Kobo'an dam	720	0.7				1	1.4	4.2					4.2
	680	0.7											
	640	1.4											
Subtotal	500				10.8			53.7				256	320.5
Fan	500	1.7							1.7	20	1	34	34
No. 1 Overflow Area	410	1.9											
No. 2 Gn. Jugo	330	1.9											
No. 3 Overflow Area	260	2.0											
No. 4 Overflow Area	190	2.8											
	140	5.1											
No. 5 Overflow Area	60	2.8											
Subtotal	0											34	34

Table-3.9 Estimated Sediment Volume of Products in K. Mujur Basin

			Gully Wall Failure			Lateral Erosion			Downward Erosion				Total
	Elevation m	Length km	HW m	NW	Volume x 1000m³	Ho m	Lo km	Volume x 1000m³	Lc km	Bc m	Dc m	Volume x 1000m³	Volume x 1000m³
B. Tunggeng	2000 – 1820												
	1820 – 1350	1.7	20	2	0.8				1.7	30	3	153	153.8
	1350 – 1000	2.6	40	17	13.6				2.6	30	3	234	247.6
	1000 – 750	3.3	30	21	12.6				3.3	30	1	148.5	161.1
	750 – 650	1.3	10	4	0.8								0.8
B. Sat Conf.	650 – 450	4.0	5	22	2.2								4.4
Subtotal				66	30.0							535.5	567.7
B. Sat	1820 – 1350	1.7	20	5	2.0				1.7	30	3	153	155
	1350 – 910	3.1	20	8	3.2				3.1	30	3	279	282.2
	910 – 750	2.5	10	2	0.4	2.5	4.5	33.75	2.5	40	1	100	134.15
	750 – 650	1.8	10	3	0.6	1.5	2.5	11.25					11.85
B. Tunggeng Conf.	650 – 450	3.8	5	3	0.3								0.3
Subtotal				21	6.5			45.0					583.5
K. Mujur Conf.	450 – 290	4.7											
Gesang	290 – 150	5.9											
Mujur Bridge	150 – 80	5.2											
K. Pancing Conf.	80 – 40	3.4											
Sea	40 – 0	5.5											
Subtotal													

Table-3.10 Sediment Balance of K. Rejali Basin (Lahar of 1981) (x 1000m^3)

			Volume Produced									Volume Deposited				
	Elevation	Length	Land-slide	Valley Shoulder Erosion	Surface Erosion	Sub-total	Valley Wall Landslide	Lateral Erosion	Valley Bed Erosion	Sub-total	Total	Flood Area	River* Course	Total	Inflow Volume	Outflow Volume
Curah Lengkong	3000 2000		633	0		633					633				0	633
	1000	5.2	0	0	0	0	10.4	+	x 3m 468	478.4	478.4	0	+	0	633	1111.4
	820	2.3	0	0	0	0	4.8	21.6	x 1m 92	118.4	118.4	0	41	41	1111.4	1188.8
Conf.	720	1.4	0	0	0	0	0	0	0	0	0	0	0	0	1188.8	1188.8
Subtotal			633	0	0	633	15.2	21.6	560	596.8	1229.8	0	41	41		
B . Kobo'an	2000 1000	5.3	0	0	0	0	7.2	+	x30 x1m 159	166.2	0	0		0	166.2	
	820	2.3	0	0	0	0	2.4	27.9	x30 x1m 69	99.3	99.3	0	31	31	166.2	234.5
Conf.	720	1.4	0	+	0	0	1.2	21.6	40x0.5 28	50.8	50.8	0	24	24	234.5	261.3
Kobo'an dam	680	0.7	0	+	0	0	0	4.2	0	4.2	4.2	0	131.7	131.7	1450.1	1322.6
	640	0.7	0	0	0	0	+	+	0	0	0	0	87.0	87.0	1322.6	1235.6
	500	1.4	0	0	0	0	+	+	+	0	0	0	0	0	1235.6	1235.6
Subtotal			0	0	0	0	10.8	53.7	256	320.5	320.5		273.7	273.7		
Fan	500 410	1.7	0	0	0	0	+	0	x20 x1m 34	34	34	0	0	0	1235.6	1269.6
No. 1	330	1.9	0	+	209.5	209.5	+	0	0	0	209.5	200.4	77.0	277.4	1269.6	1201.7
No.2 Gn. Jugo	260	1.9	0	+	223.3	223.3	+	0	0	0	223.3	178.4	98.4	276.8	1201.7	1148.2
No. 3	190	2.0	0	+	249.6	249.6	0	0	0	0	249.6	320.3	136.5	456.8	1148.2	941.0
No. 4	140	2.8	0	+	59.4	59.4	0	0	0	0	59.4	98.5	135.5	234.0	941.0	766.4
	60	5.1	0	0	66.4	66.4	+	0	0	0	66.4	87.0	101.0	188.0	766.4	644.8
No. 5	0	2.8	0	+	119.5	119.5	+	0	0	0	119.5	245.4	248.0	493.4	644.8	270.9
Subtotal					927.7	927.7	0	0	34	34	961.7			1926.4		

\+ Although its presence is likely, the value is considered nearly 0. * Includes terraces in valleys.

Table-3.11 Sediment Balance of K. Mujur Basin (Lahar of 1981) (x 1000m³)

			Volume Produced									Volume Deposited				
	Elevation	Length	Land-slide	Valley Shoulder Erosion	Surface Erosion	Sub-total	Valley Wall Landslide	Lateral Erosion	Valley Bed Erosion	Sub-total	Total	Flood Area	River* Course	Total	Inflow Volume	Outflow Volume
B . Tunggeng	2000 1820		85.0			85					85				0	85
	1350	1.7	0	127.5	360	487.5	0.8	+	30x3m 153	153.8	641.3	144	0	144	85	582.3
	1000	2.6	0	195	26.3	221.3	13.6	+	30x3m 234	247.6	468.9	49.9	0	49.9	582.3	1001.3
	750	3.3	0	99	61.6	160.6	12.6	+	30x1m 148.5	161.1	321.7	135.1	0	135.1	1001.3	1187.9
	650	1.3	0	6.5	35.3	41.8	0.8	+	+	0.8	42.6	49.8	+	49.8	1187.9	1180.7
	450	4.0	0	230.0	149.9	169.9	2.2	+	+	2.2	172.1	238.9	115.0	353.9	1180.7	998.9
Subtotal			85.0	448	633.1	1166.1	30.0	0	535.5	565.5	1731.6	617.7	115.0	732.7		
B . Sat	1820 1350	1.7	0	85	230.3	315.3	2.0	+	30x3m 153	155	470.3	92	0	92	0	378.3
	910	3.1	0	0	0	0	3.2	+	30x3m 279	282.2	282.2	0	0	0	378.3	660.5
	750	2.5	0	0	0	0	0.4	33,75	40x1m 100	134.15	134.15	0	50	50	660.5	744.65
	650	1.8	0	0	0	0	0.6	11.25	+	11.85	11.85	0	9	9	744.65	747.5
	450	3.8	0	0	160.3	160.3	0.3	+	+	0.3	160.6	226.5	383	609.5	747.5	298.6
Subtotal			0	85	390.6	475.6	6.5	45	532	582.5	1059.1	318.5	442	760.5		
Mujur Conf.	450	1.7	0	+	288.8	288.8	0	+	+	0	288.8	422.4	250.0	672.4	1297.5	913.9
Gesang	150	5.9	0	+	78.4	78.4	0	+	+	0	78.4	169.5	301	470.5	913.9	521.8
Mujur Bridge	80	5.2	0	0	35.9	35.9	0	+	+	0	35.9	58.9	99	157.9	521.8	399.8
K. Pancing Conf.	40	3.4	0	0	20.0	20.0	0	0	+	0	20.0	35.5	89.6	125.1	399.8	294.7
Sea	0	5.5	0	0	33.3	33.3	0	0	+	0	33.3	77.8	228.5	306.3	294.7	21.7
Subtotal			0	0	456.4	456.4	0	0	0	0	456.4	764.1	958.1	1732.2		

+ Although its presence is likely, the value is considered nearly 0. * Includes terraces in valleys.

Fig.-3.4 Sedimentary Balance of K. Rejali Basin (Lahar of 1981)

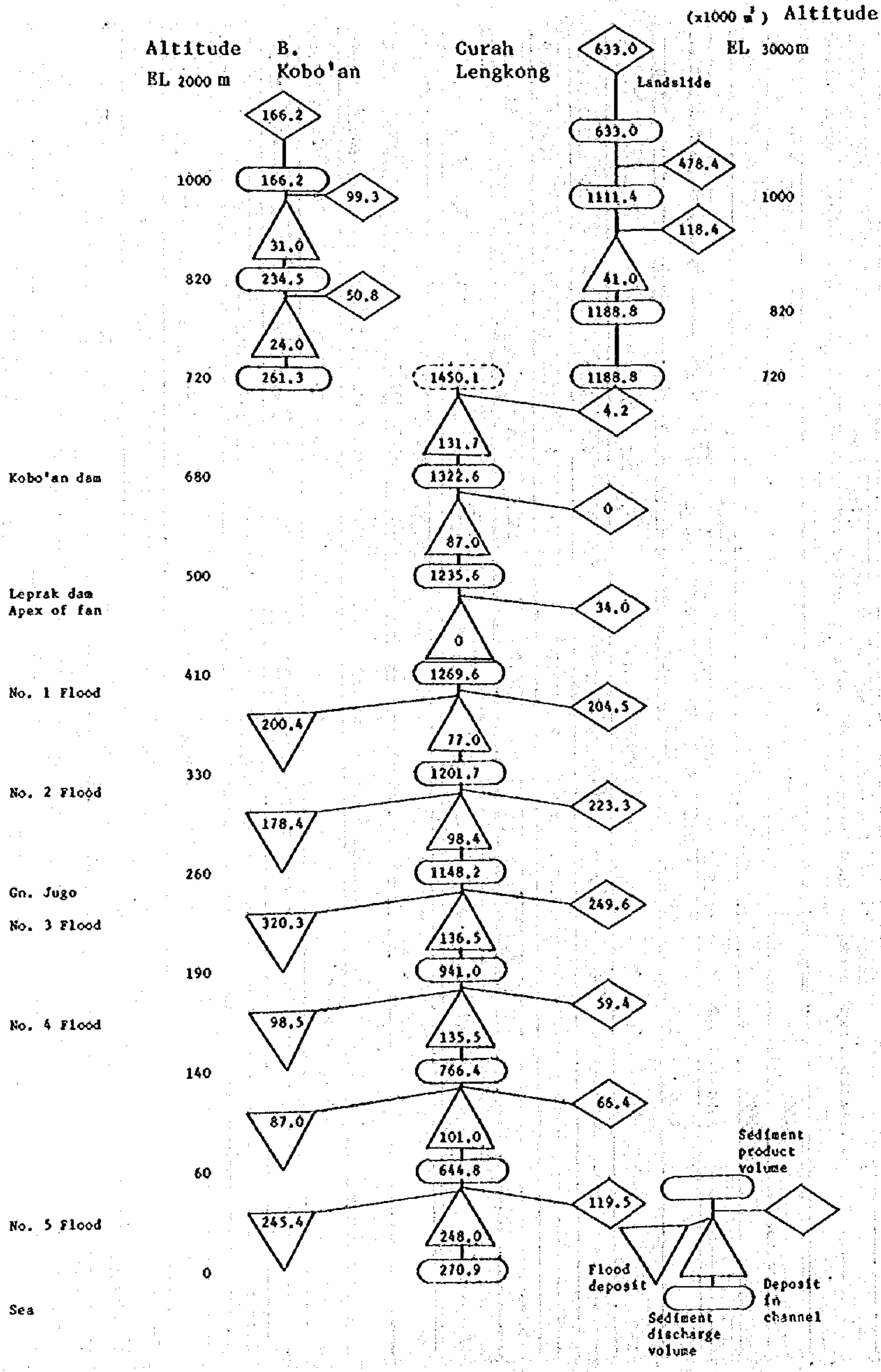
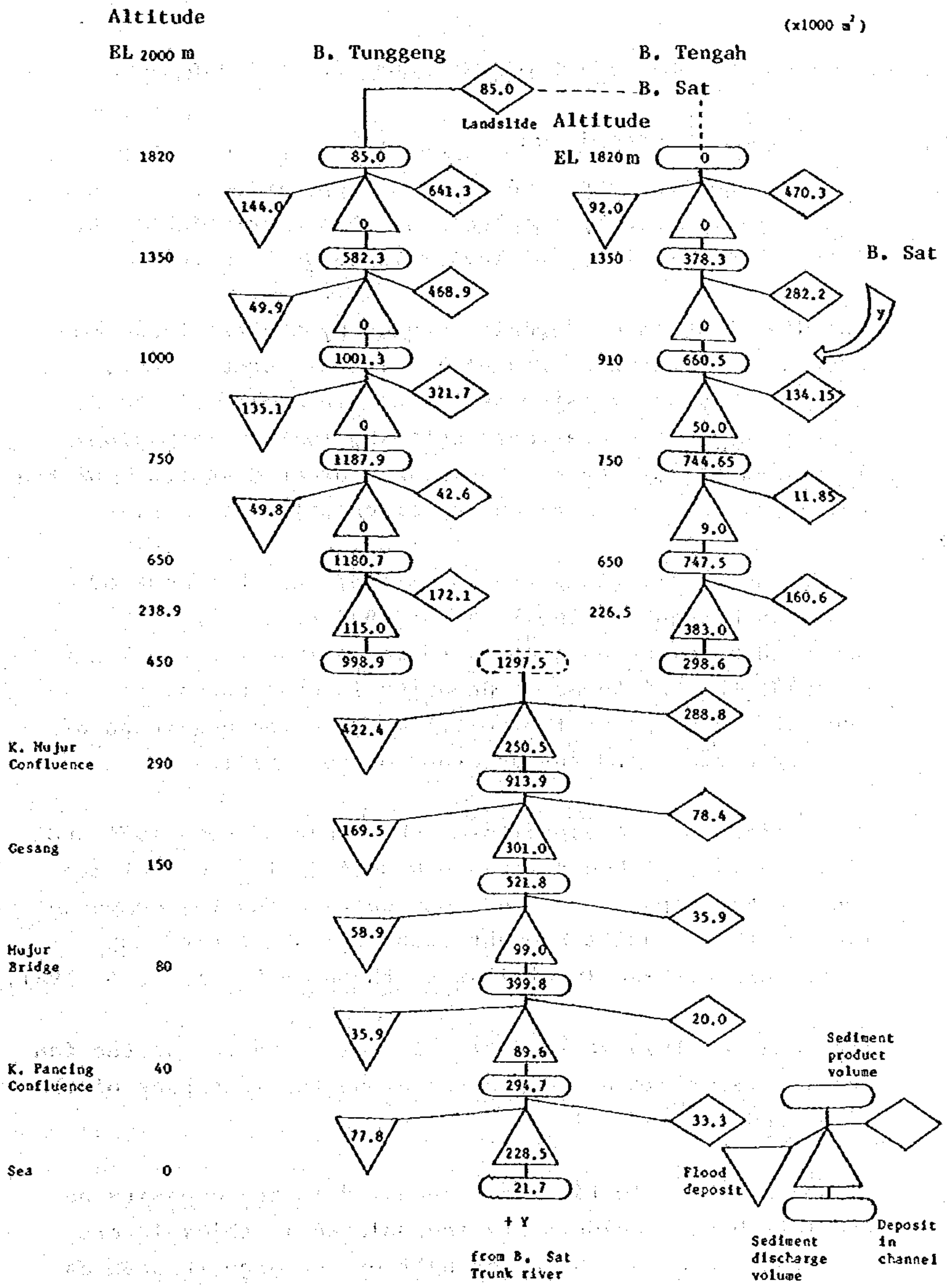


Fig.-3.5 Sedimentary Balance of K. Mujur Basin (Lahar of 1981)



4 CONDITIONS OF DEPOSITION OF THE LAHAR OF 1976 AND 1978

(1) Conditions of Deposition

In this section, the conditions of deposition over the K. Rejali fan caused by the lahar which occurred in the K. Rejali basin in 1976 and 1978 will be dealt with.

The distribution of deposits caused by the two lahar occurrences is shown in Fig.-4.1. In both occurrences, lahar mainly accumulated at the upstream side of the K. Leprak, i.e., the area corresponding to the steep-slope lahar fan at EL. 500 m - 260 m. In areas downstream of the Gn. Jugo, lahar terminated inside existing streams.

As far as observations are concerned, the thickness of deposits brought by the lahar of 1976 reaches 2 m. Although no clear outcrops were recognized for the lahar of 1978, the thickness of deposits is considered, in general, to be about 1 m to 0.5 m, from the condition of the depositions and the outcrops on some rills.

The surface of the deposits of the lahar of both 1976 and 1978 is flat; although large boulders (1 m to 2 m) are seen on the deposits. The cross section and the composition of the deposits brought about by both lahar occurrences are noticeably similar to those of the lahar of 1981.

The lahar of 1976 started flooding near the top of the fan and its materials are deposited along the left bank of the river and its channel.

Although no imbrication is recognized in the deposits on the left bank, boulders are accumulated in thick layers near the center of the upper half of the deposit area as indicated in Fig.-4.1.

Furthermore, the deposits on the fan surface along the channel are considered to have increased the relative depth of the river near the fan top and to have moved the point of flood occurence of later lahar ('78 and '81) downstream. The increase in the relative river depth was possibly further accelerated by the lowering of the river bed as a result of the K. Leprak No.1 Dam, built after 1978.

· The flood area of the lahar of 1978 is very similar to that of the lahar of 1981, the former is considered to have been smaller in scale in respect of the distribution area and deposit thickness.

(2) Calculation of Volume of Deposits

The volume of deposits resulting from the two lahar occurrences ('76 and '78) was calculated by temporarily assuming a deposit thickness distribution similar to the lahar of 1981 in scale, based upon the extent of deposits of the two lahar occurrences. In other words, the volume of deposits (Ve) for sections at the same elevation is

$$Ve = Ae \times He$$

Where,

Ae: Area of deposits

He: Average thickness of deposits of lahar of 1981

The total volume of the deposits, therefore, can be obtained by addition of Ve. The volume of deposits in the section lying at EL. 500 m to 260 m inside the K. Leprak is as follows:

Table-4.1 Volume of Deposits of Past Lahar

	1976	1978	1981
Volume of deposits (x 1000 m)	1224.0	286.0	554.2

Table-4.2 Volume of Sediment Deposited by the Lahars of 1976 and 1978

Lahar	Location	Flood Area (x 1000m^2)	Depth (m)	Deposit Volume (x 1000 m^3)
1976	a	730	0.60	438.0
	b	280	0.60	168.0
	c	170	0.60	102.0
	d	480	0.56	268.8
	e	20	0.60	12.0
	f	420	0.56	235.2
	Total	2100		1224.0
1978	g	300	0.60	180.0
	h	70	0.56	39.2
	i	120	0.56	67.2
	Total	490		286.4

5 SUMMARY

The studies clarified the conditions of sediment production, distribution of deposits and volume of transport thereof, of the lahar of 1981. Based upon these findings, the extent of lahar and a distribution of thicknesses of the deposits at the time of disaster were assumed. The results of such an attempt provided points to be noted for sediment control planning which include,

(1) The condition of the source of debris between the K. Rejali and K. Mujur basins differs considerably, however, through inference from past conditions, the source could be debris as a result of erosion of the volcanic bare slopes and the inside of valleys downstream thereof.

(2) The valleys which are most likely to produce lahar are therefore Curah Lengkong, whose source head consists of volcanic bare slopes and B. Sat and B. Sarat and B. Bang, having the same conditions in respect of their valley heads. The B. Tunggeng can be described as a valley which is less likely to cause lahar.

(3) The volume of produced sediment as a result of landslides at the source head is in the order of one hundred thousand cubic meters or there about. The volume increases as lahar flows downstream by collecting materials on the mountainsides and inside valleys at the upper reaches of the river. The volume of sediment discharge into fans will be about 1 million to 1.5 million cubic meters.

(4) Such sediment flows downstream as 1) debris flow, 2) mudflow-A, 3) mudflow-B or 4) bed load flow, names given in terms of the classification of the mode of accumulation under the present study.

(5) In many cases, the flooding points of lahar are found at areas with low embankments, bending sections of channels and points of shift in slope in the fan area.

(6) The fans under study are subject to the influence of the Semeru volcano, which actively produces a lot of materials, and therefore, they can be described as being under development.

Flood areas move due to erosion of fan surfaces and channels and the presence of deposits. In this respect, it can be assumed that the probability of flooding in the fan areas is identical within one fan area.

(7) The distribution of the deposit thicknesses of sediment has a clear tendency to thin out from the upper to the lower reaches of a river. Maps of the distribution of sediment deposit thickness were prepared with reference to this tendency and the findings given in (6).

THE REPUBLIC OF INDONESIA

THE FEASIBILITY STUDY ON THE VOLCANIC DEBRIS CONTROL AND WATER CONSERVATION PROJECT IN THE SOUTHEASTERN SLOPE OF MT. SEMERU

SUPPORTING REPORT (5)

PART - K

MUDFLOW WARNING SYSTEM

FEBRUARY, 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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1. PRESENT CONDITION OF OBSERVATION AND W. SYSTEM

As it was mentioned in Chapter 2.5, big lahar flood occurred at the southeastern slope of Mt. Semeru in 1909. It is recorded that 208 people were killed, many houses were swept away and many hectares of rice fields were damaged. Since then, the government made some efforts to control flood by using embankments. Also some observation stations equipped with telephones for warning were set up to observe the activity of Mt. Semeru and lahar.

1.1 VOLCANOLOGICAL OBSERVATION STATION

To observe the activities of Mt. Semeru, there are 3 volcanological stations at the eastern and southern slopes of the mountain. These 3 volcanological stations are:

① Tawonsongo volcanological observation station (+800 m), situated at the eastern slope area and observing the mountain activities to eastern slope direction.

② Gunung Sawur Volcanological observation station (+800 m), situated at the southeastern slope area and observing the mountain activities to southeastern slope direction.

③ Arqosuko Volcanological observation station (+900 m), situated at the southern slope area and observing the mountain activities to southern slope direction.

Observation of Mt. Semeru activities is run by the directorate of Volcanology. Communication is done by telephone.

From the location of these volcanological observatin stations, it can be concluded that volcanic debris Mt. Semeru is current produced toward the eastern and southern slope directons.

1.2 FLOOD OBSERVATION STATION

Since the occurrence of lahar flood in 1909, the government paid a serious attention to control lahar flood. Besides constructing some countermeasures such as embankments and revetments, 10 flood observation stations were set up at the eastern and southeastern slopes of the mountain. Communication system between these observation consist of telephones, where its management comes under the Irrigation Service of Lumajang. Therefore, Central Station of the telephone communication system is at the Irrigation Services Office.

Those flood observation stations are as follows:

1. Kertosari Central Observation Stations is to observe lahar in the Besuk Sat river, located at the mid-stream of the river. ("Central station" means that some stations in the field is subordinate to this station).

2. Gunug Sawur Central Observation Station is to observe lahar in the Besuk Semut river, located at the upstream of the river.

3. Curah Kobo'an Observation Station is to observe lahar in the Besuk Kobo'an river, located at the mid-stream of the river.

4. Kali Pancing Observation Station is to observe lahar in the Pancing river.

(5) Besuk Sat Observation Station is to observe the Besuk Sat river. located at upstream of the river.

(6) Mungir Observation Station is to obsrve lahar inthe Besuk Sat river, located at the downstream of the river.

(7) Bendo Observation Station is to obsrve lahar in the B. Sat river, located at mid-stream of the river.

(8) Senduro Observation Station is to observe the Ireng-ireng river

(9) Pagoan Observation Station is to observe the Laban river.

(10) Kedung Waringin Observation Station is to observe the Mujur river.

1.3 TRADITIONAL WARNING SYSTEM

Traditional warning system is still convenient in the area surrounding Mt. Semeru, especially in the country side to announce the occurrence of lahar flood (also for fire, etc.). This traditional warning devise is called Kentongan (Tong-tong), made from bamboo or hollow wood.

To announce the occurrence of flood, people beat these tong-tong in a certain rythm, and the alarm is repayed to the neighbouring villages so as to make up the people to prepare the emergency evacuation.

1.4 RADIO WARNING SYSTEM

After the establishment of Mt. Semeru Project, a radio communication system will be installed to improve warning system owned by the Irrigation Services Office (at Lumajang).

Location of the radio stations will be as follows.

- Semeru 1. At the Mt. Semeru Project Office
  At the central communication station
- Semeru 2. At the Kobo'an Observation Station, observing and reporting the occurrence of flood in the B. Kobo'an river
- Semeru 3. At the B. Sat Observation Station, observing and reporting lahar flood in the B. Sat river
- Semeru 4. At the Kecamatan Pronojiwo Office, observing and reporting flood in the Lengkong river and its tributaries

1.5 LGTC WARNING SYSTEM

Recently (1982/1983 fiscal year), Mt. Semeru Project Office set up a more convenient communication system. It is called Local Government Tele-Communication System (hereinafter referred to as LGTC system). The communication system using radio equipment, whereby communication can be done by those who hold the radio device. (Conveyable distance is about 50 km - radius)

Warning system network showing the Irrigation Services Telephone and Radio Communicaitions and Reporting System are given in Fig.-1.1. Locations of observation stations are shown in Fig.-1.2.

1.6. EVACUATION HILL

During a flood, poeple will be evacuated to an evacuation hill which is made from tones or soil some 3 m high sbove the ground. This evacuation hill is used for the purpose of saving lives during flood. However, a lahar directly attacks this evacuation hill, it is not storng enough to bear the destructive power of lahar stream. Therefore, it is advisable to construct it much stronger.

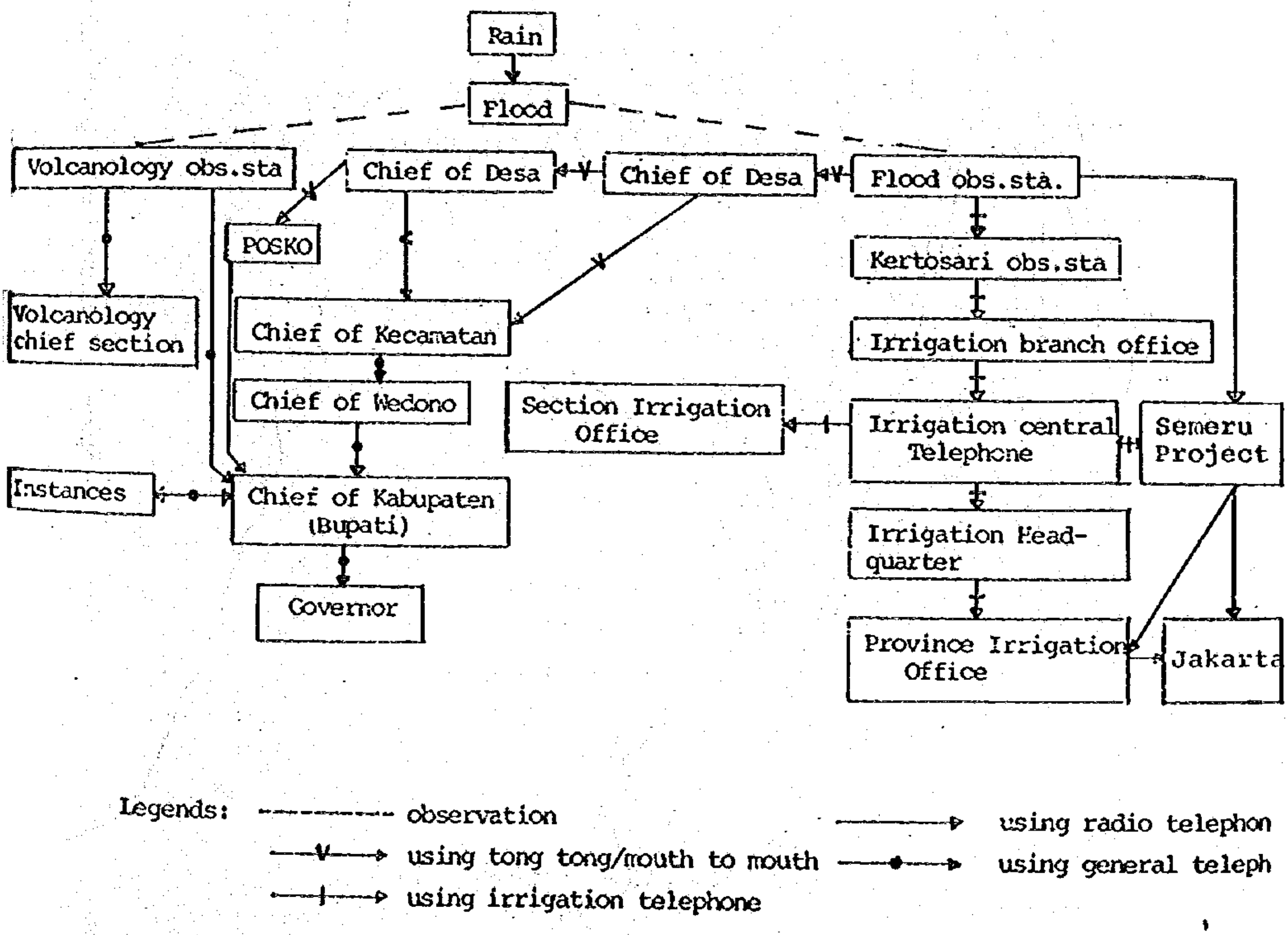


Fig.-1.1, Warning System

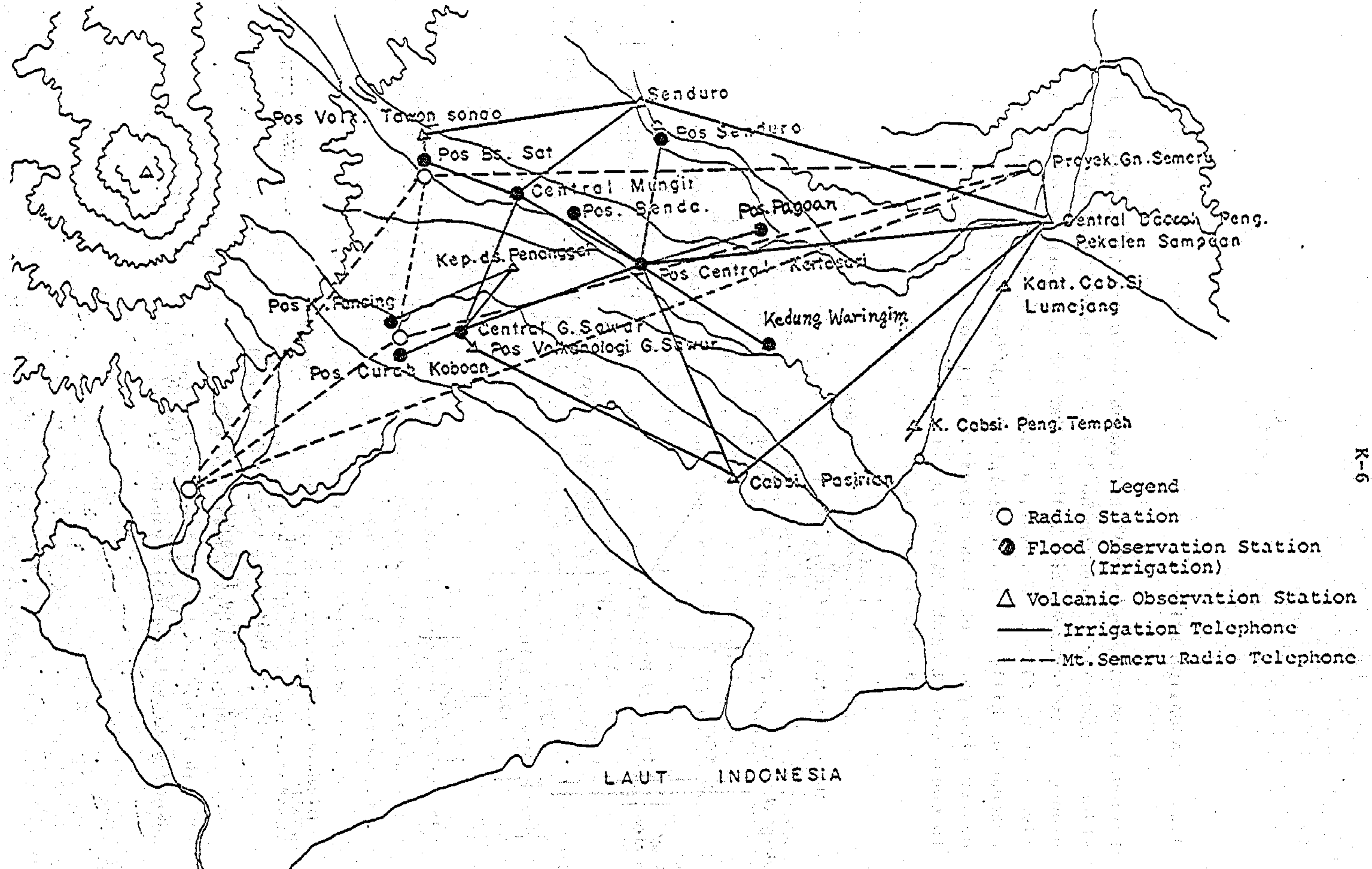


Fig- 1.2 Location Map of Warning System

2. GENERAL COMMUNICATION CIRCUIT PLAN

2.1 OUTLINE

Due to the volcanic activity of Semeru Volcano, an enormous amount of volcanic ash, earth and rocks deposited over a long period of time, when saturated with rain will start to shift, and depending on the rainfall, will suddenly move and flow down causing a great deal of damage to the fields, property and people's lives in the area.

Therefore, besides enforcing such preventive measures as sediment control works from the civil engineering standpoint, the Mudflow Warning System as described below will play an important role.

Because the mechanism and interrelation of cause and effect of mudflow were found to be mostly due to the rainfall in the surrounding area, sub-systems were installed to this system as described below.

Each sub-system is a social system designed mostly to protect the lives and property of the inhabitants. By catching the occurrence of mudflow on the upper stream around 2,000 m above sea level on the side of the Semeru Volcano using the Information Processing Center's sensor and TV camera (normally used to collect data on rainfall, water level and visual information), the danger of the mudflow reaching the lower stream can be predicted and an evacuation warning due to mudflow can then be transmitted to the danger zones.

At the Center, the conditions of rainfall are observed by a small radar raingauge and the actual measure of precipitation and water level is automatically collected by the rainfall and water level telemetering system to prepare for the occurrence of mudflow. The collected data is digitally displayed on the display panel and recorded with a typewriter.

When mudflow occurs, it is detected by a sensor which is installed upstream which then proceeds to inform the Center. At the center the place of mudflow is pinpointed on the map panel of the graphic display and the occurrence is acknowledged by the sounding of a buzzer.

By monitoring the pictures taken by the TV camera in the field, the condition of the occurrence of mudflow is understood at the Center.

The pictures are recorded by VTR as required. The rising of the water-level down stream is monitored through a water-level telemetering system and a dangerous water-level can be predicted in advance, dispalyed on the map panel and acknowledged by the buzzer.

Based on data collected in this way, the relationship between the occurrence of mudflow and total rainfall and its intensity; calibration of radar raingauge by rainfall telemeter, the trend of movement of raining zones, and mutual relation among rainfall, flowrate and water-level are learned.

A study is also made on the danger of mudflow and its effect through the field data obtained by the information system.

Based on this result, a warning can be given to the inhabitants in ordinary areas by means of the existing ordinary communication system.

For the inhabitants in hazardous areas, however, an evacuation warning is issued directly through a speaker in the field via the radio circuit of the warning system in order to issue the warning without delay.

As mentioned before this system comprises varoius sub-systems and its full function will be performed by making the organic and effective combination of these sub-systems. This system is composed of the following.

(1) Information System

① Rainfall Observation System

Small radar raingauge and rainfall telemetering system

② Water-level Observation System

Water-level telemetering system

③ Mudflow Observation System

Mudflow sensing equipment and visual mudflow measuring equipment.

(2) Information Processing System

① Information Processing Center

(3) Public Information System

① Warning System

Warning equipment

2.1.1 RAINFALL OBSERVATION SYSTEM

(1) Small Radar Raingauge

To observe rainfall by installing radar at the Center to make wide and instant rainfall observation is very effective.

The features of rainfall observation by radar are:

① Rainfall in a wide area can be observed.

② Rainfall is clearly shown on the CRT display and the situation can be confirmed by visual observaton.

③ Rainfall in part areas can be clearly defined.

④ Furthermore, since the movement of partial rainfall can be observed, rainfall in frequent mudflow areas can be easily forecast.

⑤ Various rainfall data is stored on magnetic tape and reproduced at a later date to study the mechanism of mudflow.

(2) Rainfall Telemetering System

Besides confirming the rainfall forecasts and movement with a small radar raingauge, a ground rainfall telemeter is installed to compare data with the ground raingauge which is installed at main points and so improve the accuracy of rainfall data.

It is also known as a back-up system to the small radar raingauge.

Rainfall data at each spot is transmitted by radio to the Center where the data is analysed and then printed by typewriter.

The rainfall data is processed by the telemetering supervisory equipment installed at the Center. The rainfall gauging station at each spot is called automatically at set times by the telemetering supervisory equipment which collects the rainfall data from the stations.

Manual observation is also possible at any time desired other than the set times.

When rainfall occurs at any of the rainfall gauging stations data is automatically sent to the Center, so that it can be promptly confirmed and this facilitate the issue of mudflow warnings.

2.1.2 WATER-LEVEL OBSERVATION SYSTEM

(1) Water-level Telemetering System

The main cause of mudflow is considered to be due to rainfall. For this reason, small radar raingauges and ground raingauges confirm the conditions of rainfall and issue a warning for mudflow in advance.

Furthermore, it is necessary to recognize the water-level rising conditions of main rivers.

With the increase of rainfall, floods as well as mudflow inflict a great amount of damage. Early knowledge of flood water-level is the most important part of the mudflow warning system. The water-level gauging stations installed on main rivers automatically record and store the changing water-levels on the record form and sends out the information to the Center.

It is not only sent out on demand by the Center but also automatically when the water-level at the station reaches the preset flood warning level.

2.1.3 MUDFLOW OBSERVATION SYSTEM

(1) Mudflow Sensing Equipment

The main purpose of this equipment is to sense the occurrence of mudflow and transmit the information to the Center.

This equipment is installed at the main spots where mudflow is likely to occur.

Mudflow causes strong vibrations as well as a flow of earth and rocks according to the size of the mudflow. The vibration is caught by this equipment and the information is transmitted to the Center by radio to notify the occurrence of the mudflow.

At the Center, the information is automatically received and the occurrence of mudflow is confirmed, recorded and stored on the record form.

This will make a more effective system when used in combination with the visual mudflow measuring equipment which will be described in the following paragraphs.

(2) Visual Mudflow Measuring Equipment

In most cases where mudflow occurs causing disaster, the condition of the disaster is only confirmed after the event.

It will be difficult to directly face the enormous energy of mudflow due to various limits.

Even if the field of the disaster is pinpointed, it will be difficult to record the movement of mudflow as only a still picture of the scene can be taken.

It is very important to catch the dynamic form, size and intensity of mudflow for a mudflow warning.

It is also very important to study the relations of rainfall, topographical factors, condition of occurrence of mudflow and its size, and to improve the accuracy of forecasting mudflow occurrence. Moreover, it is important to obtain basic data of civil engineering countermeasures and feed them back to the basic design of civil engineering structures.

After the aforesaid mudflow sensing equipment catches the vibration and notifies the Center, this equipment will then transmits to the Center the color pictures by radio TV transmitter, which are taken by a TV camera remotely switched from the Center showing the situation of the mudflow at a predetermined camera angle.

At the Center, the color pictures are monitored on television as well as recorded and stored on video tape.

From an academic standpoint too this is important material.

2.1.4 PUBLIC INFORMATION SYSTEM

(1) Warning System

In case of the Center judging the danger of occurrence of mudflow based on the various data obtained from the rainfall observation system, water-level observation system and mudflow observation system, it requires a warning system to notify the local population for immediate evacuation.

Issuance of an evacuation warning is done manually according to the judgement of the Center.

The warning station is installed in places where the existing ordinary communication system cannot cover, selecting dangerous areas of mudflow and fully studying the number of residences.

At each warning station, a speaker is installed on top of a mast to notify the evacuation warning through the speaker.

In the event that an evacuation warning is issued to the whole area where the warning stations are installed, all the stations will make a whole-area warning. Depending on the condition of rainfall, the warning may be issued to only part of the area, therefore, an individual area warning system is also employed.

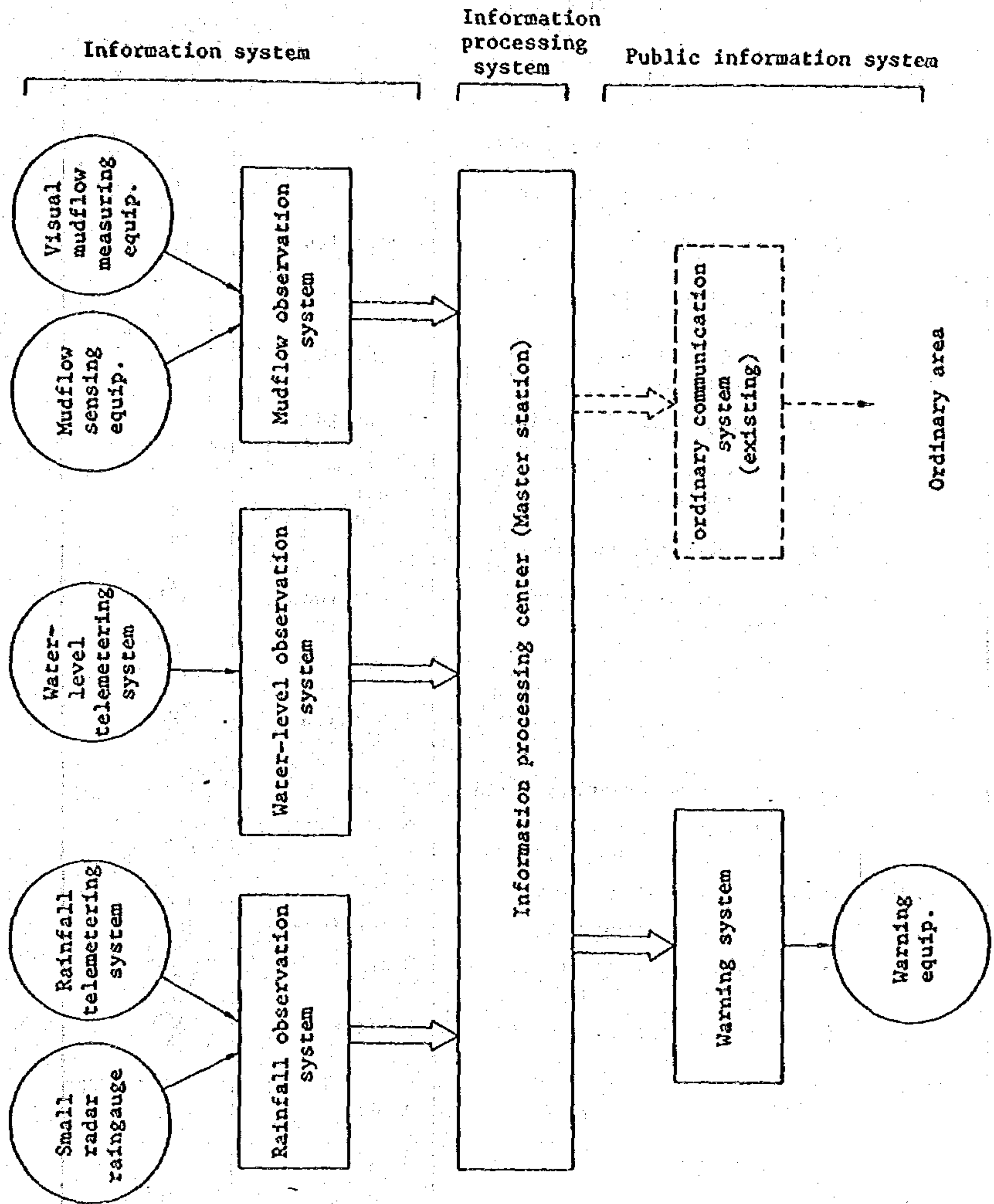
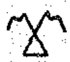


Fig-2.1 Diagram of Mudflow Warning System

2.2 Composition of Mudflow Warning System Equipment

Item No.	Description	No. of units	Remarks
1.	Information processing system	1 set	
1.1	Information processing center	1 set	
	(1) Small radar raingauge	1 station	
	(2) Telemetering supervisory station	1 station	 (for (2)–(4))
	(3) Visual mudflow receiving station	1 station	
	(4) Warning control station	1 station	
2.	Information system	1 set	
2.1	Rainfall observation system	1 set	
	(1) Telemetering monitoring station	2 stations	
	(2) Telemetering rainfall gauging station	5 stations	
	(3) Telemetering repeater station	1 station	
2.2	Water-level observation system	1 set	
	(1) Telemetering water-level gauging station	6 stations	
2.3	Mudflow observation system	1 set	
	(1) Mudflow sensing station	3 stations	
	(2) Visual mudflow measuring station	2 stations	
	(3) Mudflow repeater station	1 station	
3.	Public information system	1 set	
3.1	Warning system	1 set	
	(1) Warning station	19 stations	
	(2) Warning repeater station	1 station	

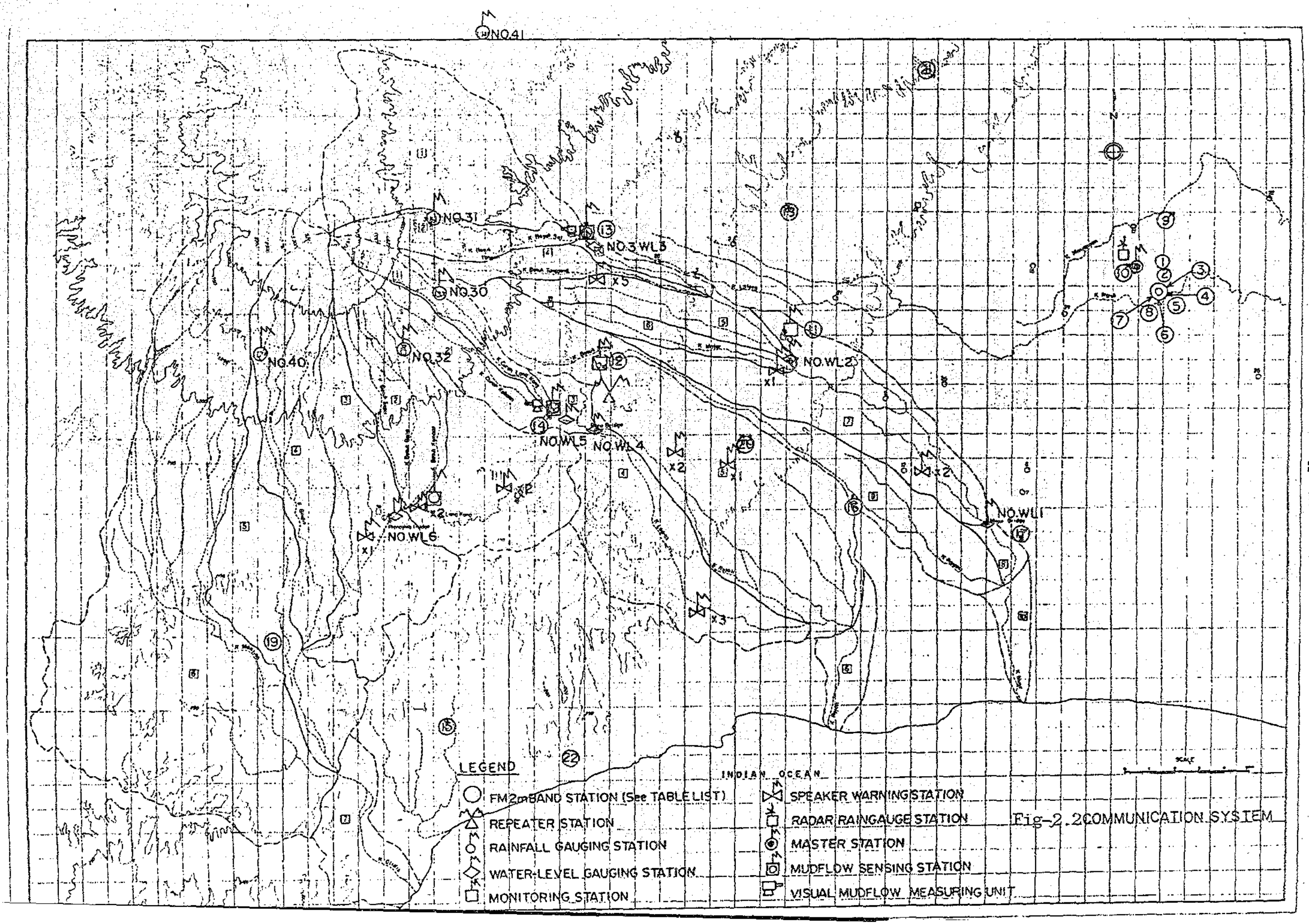


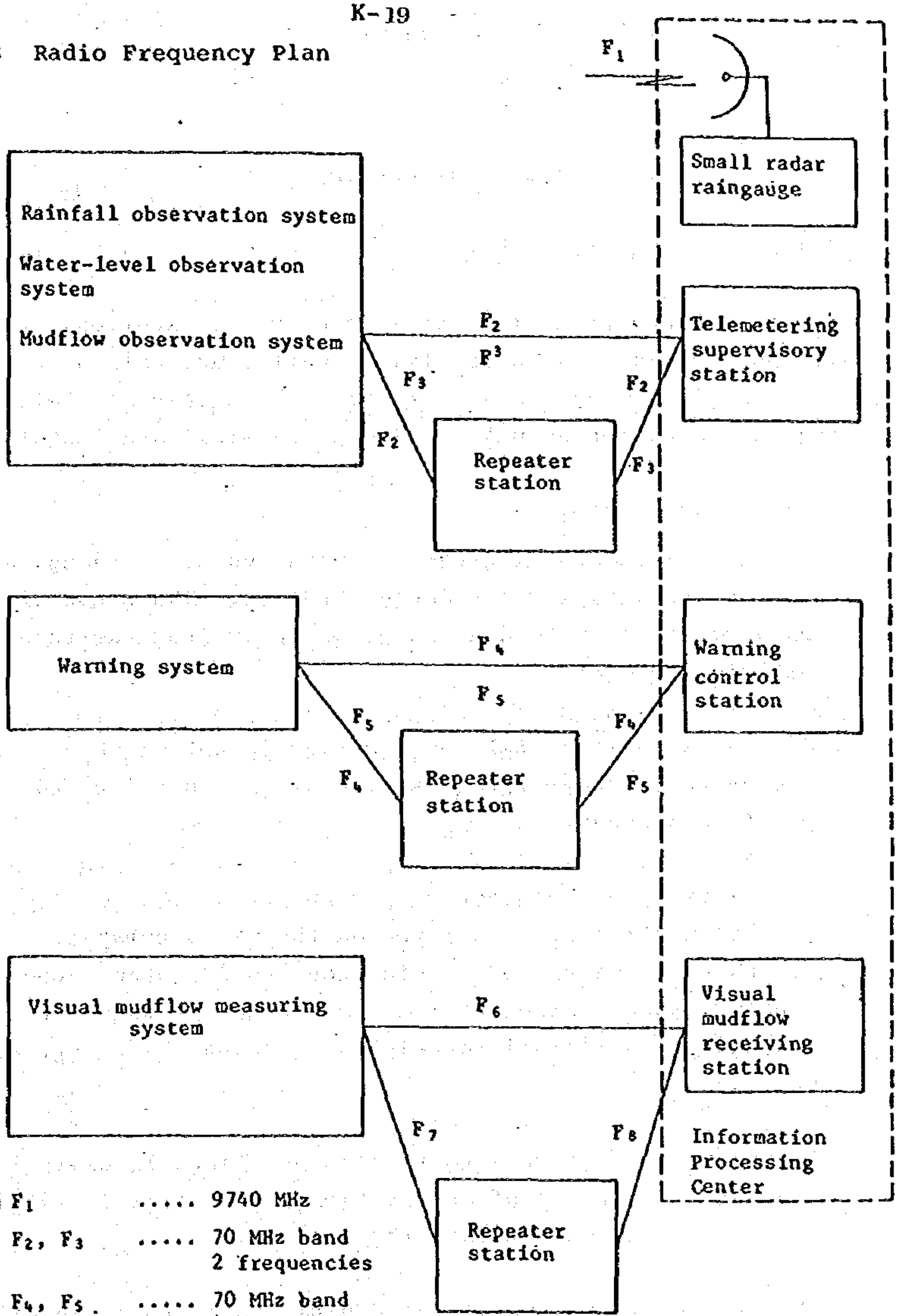
Fig-2.2 COMMUNICATION SYSTEM

FM 2m BAND COMMUNICATION SYSTEM IN LUMAJANG

TABLE LIST

STATION NO.	NOTATION NO.	STATION	FREQUENCY
ELANG I	7	PENDOPO	81.7 MHz
ELANG II	4	PEMDA	
ELANG III	6	SOSPOL	
SIAGA I	2	RUMAH SAKIT UMUM	FM 2m BAND
SIAGA II	3	POLRI	
SIAGA III	12	GN. SWAUR	80.5 MHz
SIAGA IV	10	PROYEK SEMERU	
SIAGA IV	14	CURAH KOBO'AN	
SIAGA IV	13	BESUK SAT	
SIAGA IV	5	PENGAIRAN SEKSI	
SIAGA IV	11	KERTOSARI	
SRITI I	1	KEC. KOTA	81.7 MHz
SRITI II	9	KEC. SUKODONO	
SRITI III	18	KEC. SENDURO	
SRITI IV	21	KEC. GUCIALIT	
SRITI V		KEC. KLAKAH	
SRITI VI		KEC. RANUYOSO	
SRITI VII		KEC. RANDU AGUNG	
SRITI VIII	16	KEC. PASIRIAN	
SRITI IX	17	KEC. TEMPEH	
SRITI X	20	KEC. CANDIPURO	
SRITI XI	19	KEC. PRONOJIWO	
SRITI XII		KEC. YOSOWILANGUN	
SRITI XIII		KEC. JATIROTO	
SRITI XIV		KEC. KUNIR	
SRITI XV		KEC. TEKUNG	
SRITI XVI	15	KEC. TEMPER SARI	
		P.T.P. KERTOWONO	39.3 MHz
	22	P.T.P. KAJARAN	
		PABRIK GULA JATIROTO DAN	39.9 MHz
		CABANG CABANGNYA	
		CV. INDAH PUSAT DI KENCONG	35.7 MHz
	8	CV. INDAH CAB. LUMAJANG	

2.3 Radio Frequency Plan



F_1	.....	9740 MHz
F_2, F_3	.....	70 MHz band 2 frequencies
F_4, F_5	.....	70 MHz band 2 frequencies
F_6, F_7, F_8	.....	VHF TV band 3 frequencies
Total		8 frequencies

3. INFORMATION SYSTEM (Data Collection)

3.1 RAINFALL OBSERVATION SYSTEM

In order to collect rainfall, the main cause for mudflow, as quickly and accurately as possible, a small radar rainguage suited to obtain a wide range of rainfall, and rainfall telemetering equipment for actual gauging of rainfall are installed.

3.1.1 Small Radar Raingauge

This small radar raingauge is installed at Lumajang, and observes rainfall which causes mudflow. The range of observation is within a radius of 40 km from the radar site in the center.

Observation of rainfall by radar equipment catches momen- tary area rainfall within a range of view and provides abundant data.

This data is calculated by a computer and the results of the calculation are displayed on the CRT display as growth and movement of raining zone to dangerous zone of mudflow, accumulated rainfall in the specified basin and intensity of rainfall to help forecasting the occurrence of mudflow.

In the case of a small radar raingauge installed at Lumajang, the range of observation of rainfall is within a frame on the map (within thick line).

This range of observation is divided into areas (mesh) of 250 m from east to west and 300 m from south to north and the intensity of rainfall is calculated for each mesh by radar signal and is displayed on the CRT display.

The display includes the following pictures.

(1) Display of the condition of rainfall in the whole observation range.
(80 km x 60 km) SCALE I

(2) Display of the intensity of rainfall in the specified area.
(40 km x 30 km) SCALE II

(3) Display of enlarged rainfall intensity in the specified river basin.
(20 km x 15 km) SCALE III

(4) Display of basin mean rainfall (Part 1) to display in graph of 10 minutes and accumulated rainfall in the specified river basins for the past 8 hours.

(5) Display of basin mean rainfall (Part 2) to display in graph of 1 hour and accumulated rainfall for the past 48 hours.

The display pictures can be repeatedly reproduced as required and are recorded on a floppy disc for long term file.

The intensity of heavy rain on the radar raingauge is calibrated by the ground raingauge data collected through telemetering system.

The small radar raingauge basically comprises aerial equipment, transmitter receiver equipment, signal processor equipment, CRT display and hard copy.

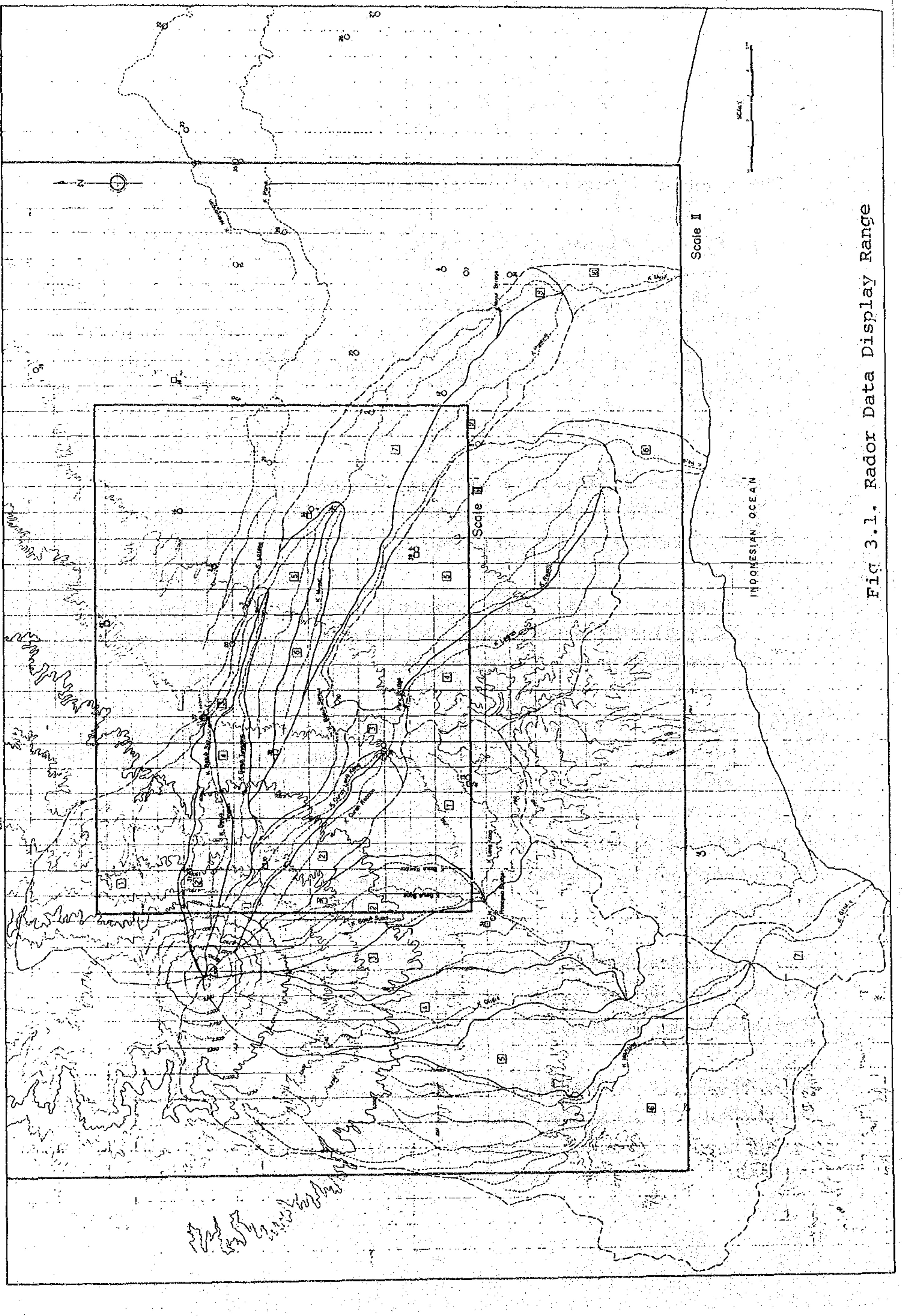


Fig 3.1. Rador Data Display Range

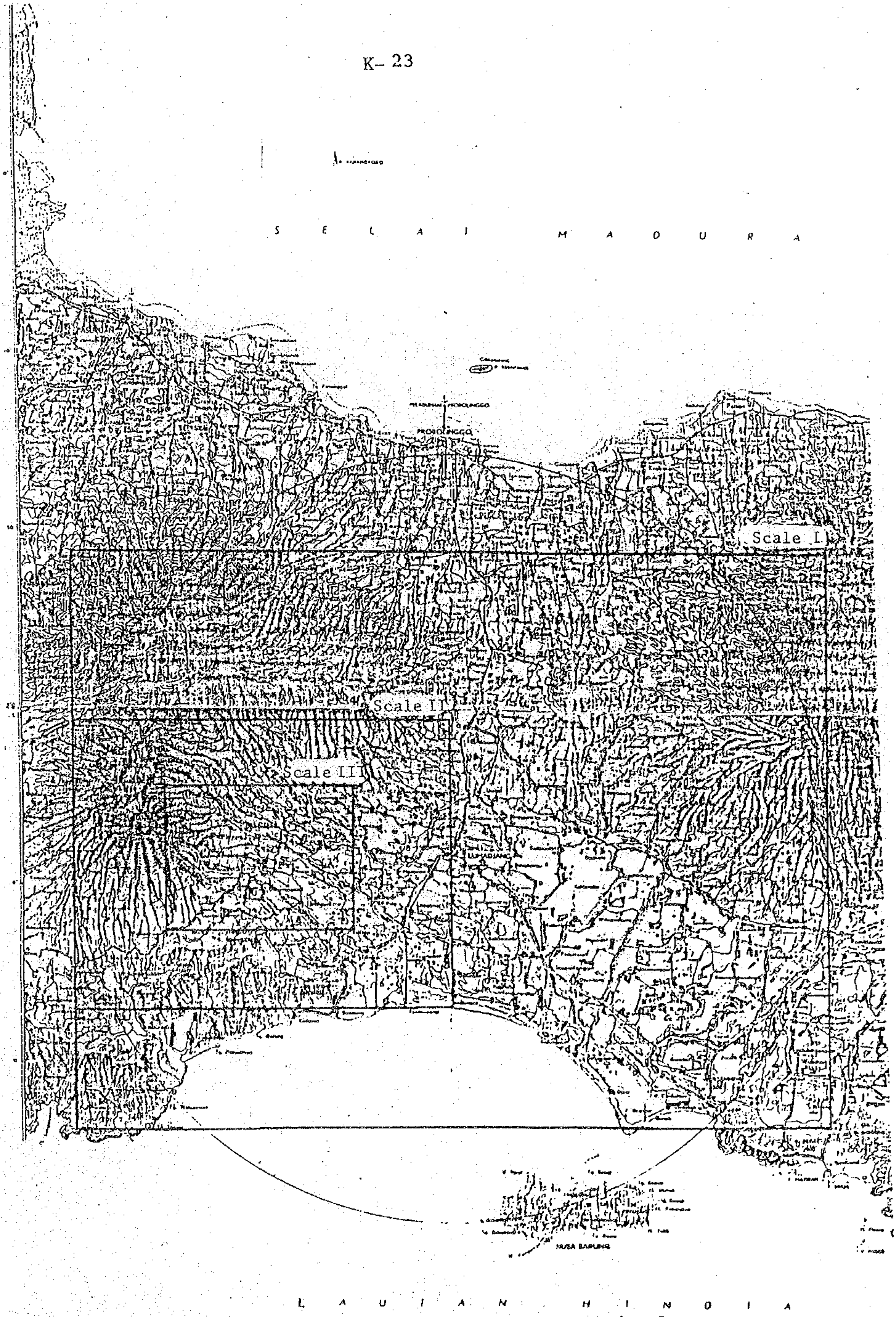


Fig 3.2. Radar Data Display Range

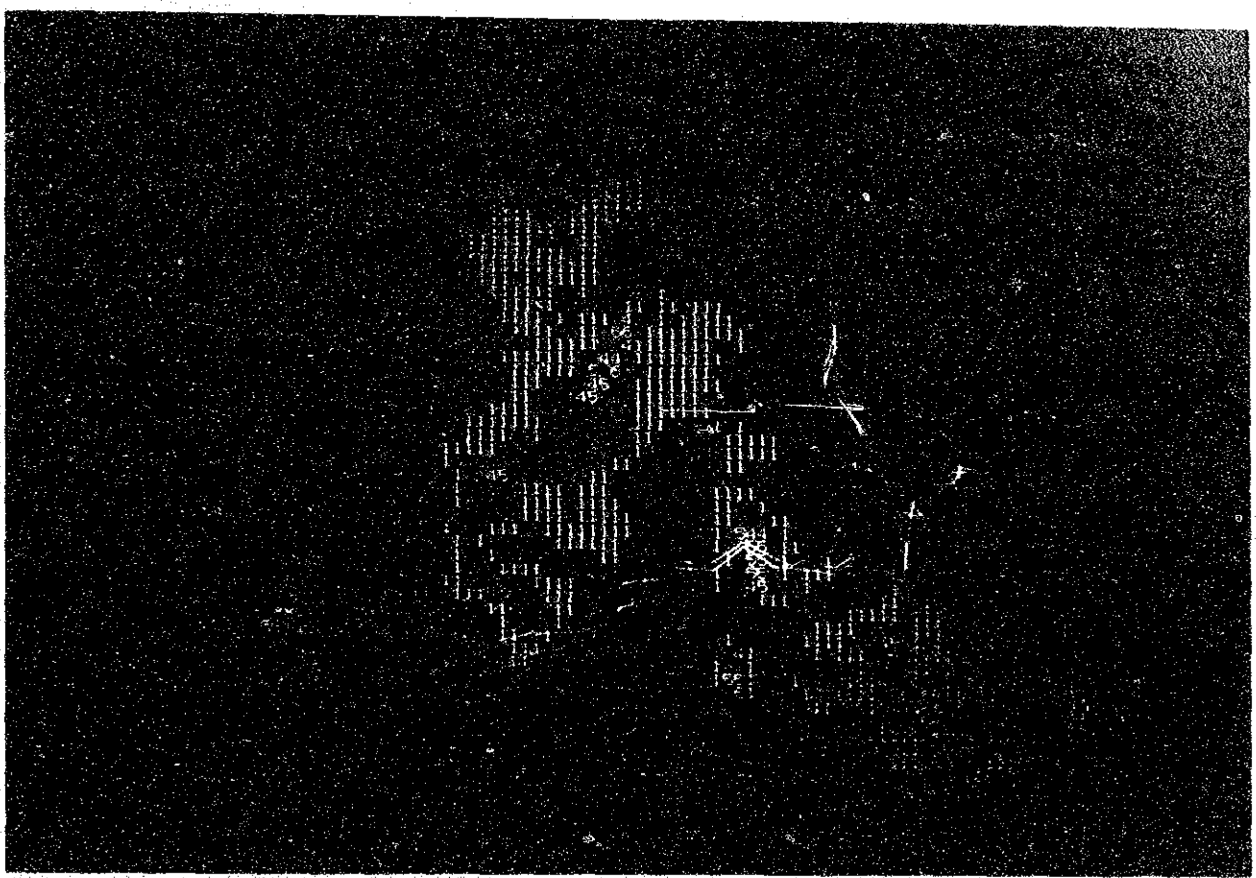


Fig 3.3. Rainfall Intensity Display

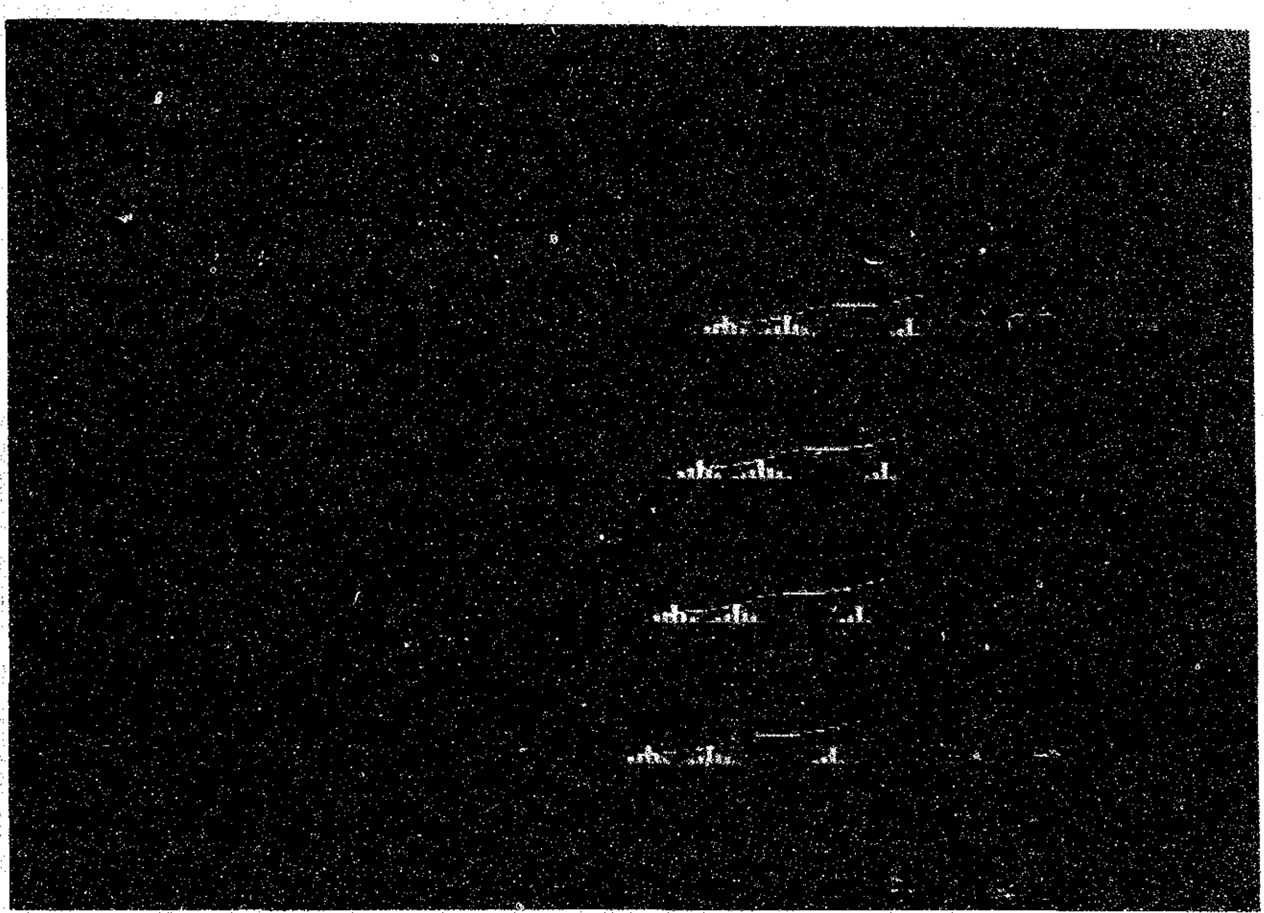


Fig 3.4. Basin Mean Rainfall Display

Radio wave emitted from radar aerial is reflected by rain, buildings and mountains within the observation range of 360 around and the reflected signals are caught by the receiver with varied intensity.

Signals measured at the receiver are removed of any unnecessary signals for observing rainfall with a signal processor. Then they are calculated/processed for the intensity of rainfall per hour according to the intensity of the signals. They are displayed in color as patterns of raining zone and characters of the intensity on the CRT display. Also on the picture, a map is shown in the back-ground as required, to enable easy determination of the size and direction of rainfall for any observer.

Also, accumulated rainfall in the specified basin is displayed to make up the highly accurate system of fore-casting mudflow. For improving the accuracy of the system, data is stored in magnetic discs and necessary pictures can be immediately taken in hard copy.

3.1.2 Rainfall Telemetering System

Rainfall data is collected automatically by controlling the rainfall gauging station from the Center and by col-lecting the rainfall measured by the tipping bucket type raingauge.

The collected rainfall data is calculated/processed to suit the judgement of the conditions of rainfall and recorded by typewriter.

Calculation/processing is done to obtain the intensity and volume of rainfall for every hour (10 minutes, 30 minutes, 1 hour and 1 day) and accumulated rainfall from start to end of the rainfall. Monitoring is carried out for exceeding the preset value. When danger is detected, a warning is issued to notify the operater.

Data processed/calculated is sorted for each station and automatically recorded by typewriter.

An automatic starting system from the gauging station is also installed, and information is automatically transmitted to the Center when the gauging station detects the start of rainfall.

Upon receipt of the signal, the Center collects data from all the stations of the gauging station and finds out from the stations where rainfall has started. Then the observation interval is automatically switched to 10 minutes and data is continuously collected to the end of the rainfall.

Calculation/processing

① 10 minutes rainfall

② 30 minutes rainfall

③ Hourly rainfall

④ Daily rainfall

⑤ Continuous rainfall

⑥ Judgement of rainfall alarm

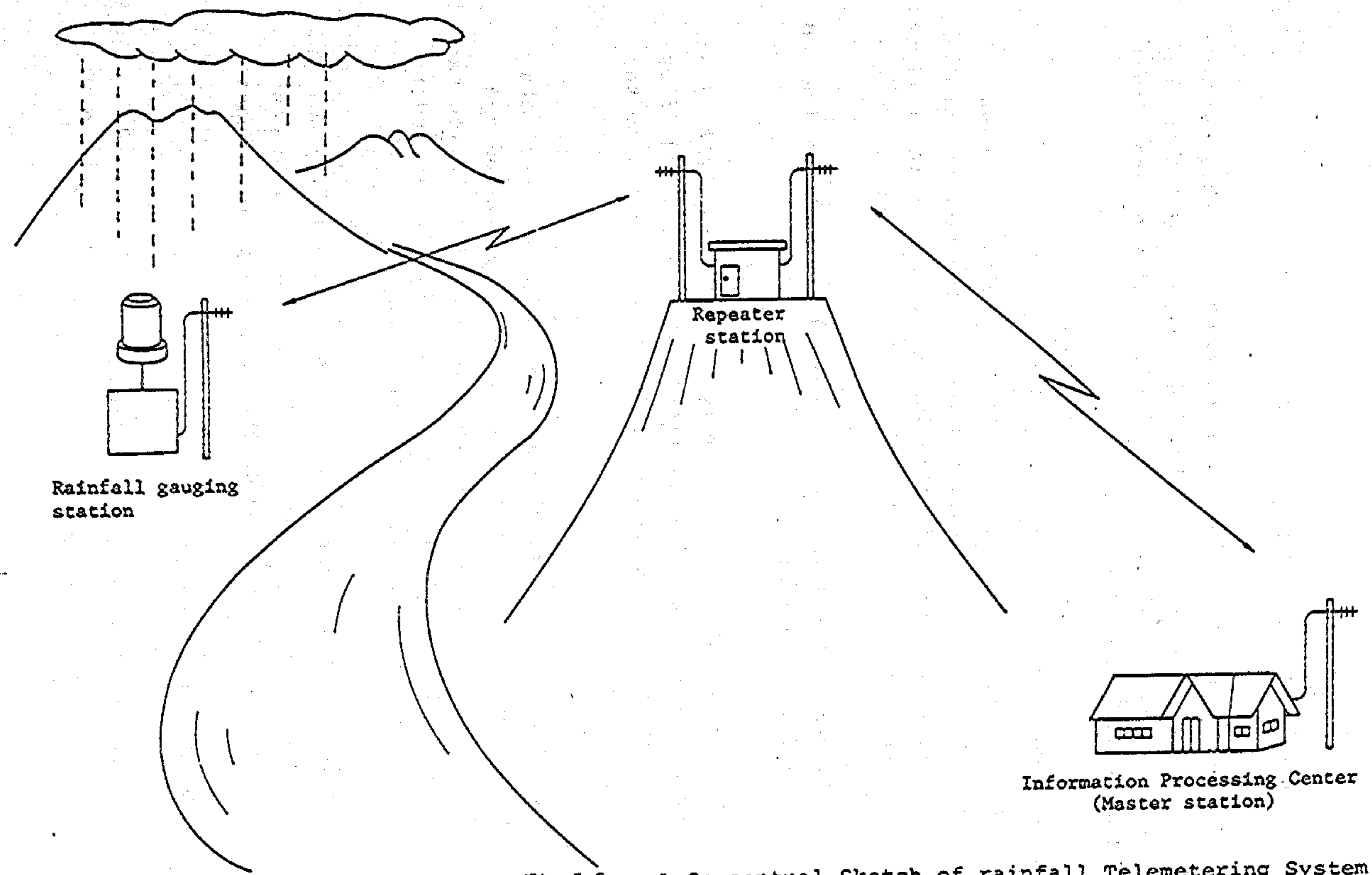


Fig-5.3 A Conceptual Sketch of rainfall Telemetering System

3.2 WATER-LEVEL OBSERVATION SYSTEM

Occurrence of heavy rain and mudflow greatly affects the water level downstream. A water-level telemetering system is installed to monitor the changing condition of the water level and dangerous water-level.

3.2.1 Water-level Telemetering System

Collection of water-level data is carried out by controlling the water-level gauging station from the Center and by automatically collecting water-level data of rivers measured by water-level meter.

Collected water-level data is sorted for each station and recorded by typewriter.

The gauging station also monitors whether the water level of rivers has exceeded the preset alarm level and if exceeded, information is automatically transmitted to the Center.

When this information is received, the center collects data from all the stations of the gauging Station and sends out a warning to the operater when the station exceeding alarm water-level is found. Then the record is typed in red for easier identification.

The interval of observation is then automatically switched to 10 minutes and a careful collection of data is continued until the warning of the water level is released.

Calculation/processing

(1) Judgement of Alarm Water-level

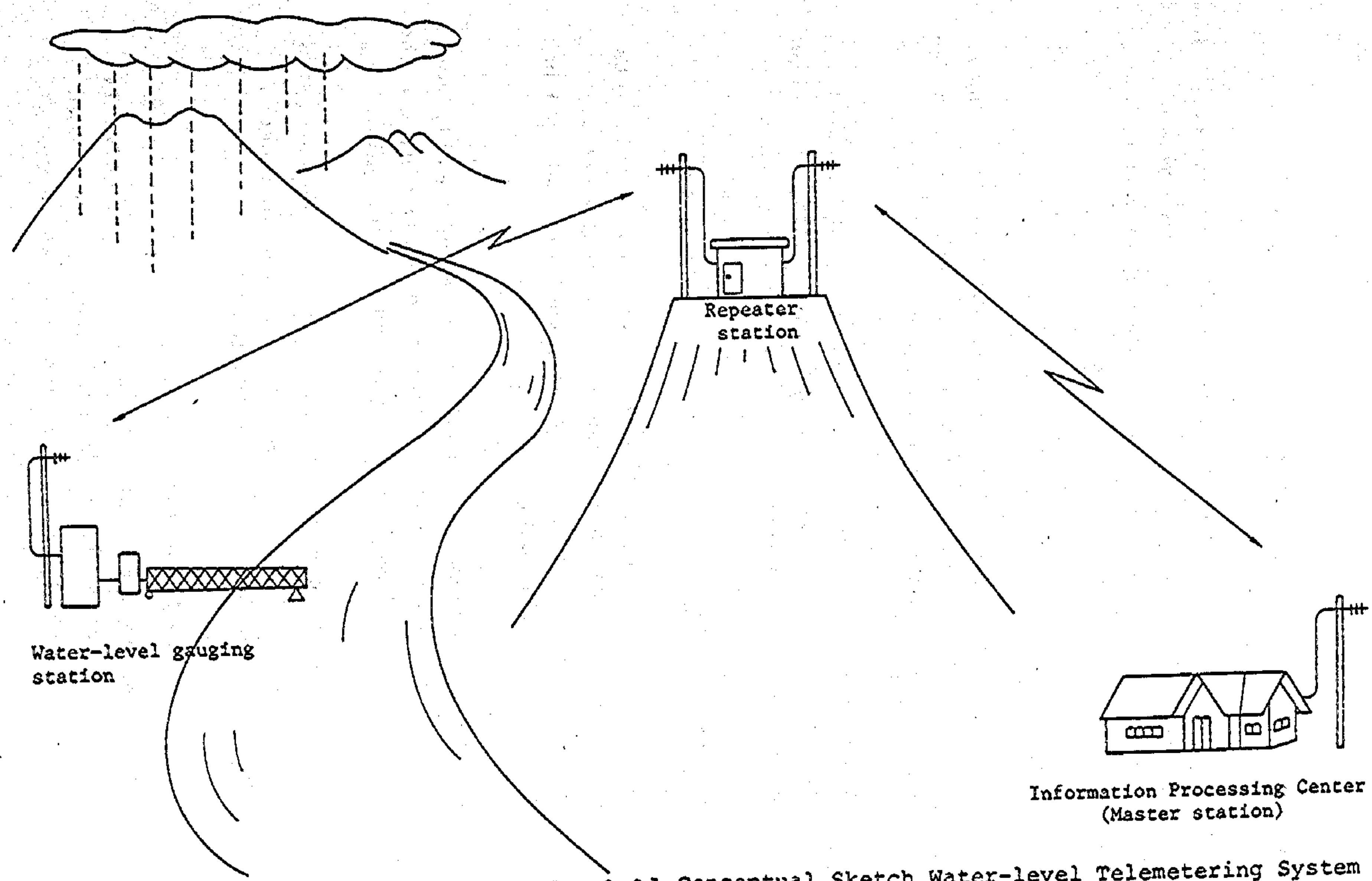


Fig-3.6 A Conceptual Sketch Water-level Telemetering System

3.3 MUDFLOW OBSERVATION SYSTEM

A visual mudflow monitoring system for monitoring the condition of mudflow at the Center is installed by combining mudflow sensing equipment to catch occurrence of mudflow and to communicate to the Center.

3.3.1 Mudflow Sensing Equipment

A vibration sensor detects vibrations travelling underground due to the occurrence of mudflow and informs the occurrence of mudflow to the Center.

A disconnection switch is also used to make sure of detection. Upon receipt of the information, the Center notifies the occurrence of mudflow to the operator by sounding a buzzer and records the date and place of occurrence with a typewriter.

The mudflow sensing equipment can connect up to 3 sets of vibration sensors and cables can be extended up to 1 km from the main body, therefore, the main body can be placed in a safe zone.

The vibration detection level can be independently set for each vibration sensor. The range of setting for the level has two stages, 0 - 10 gal and 0 - 100 gal.

Where all 3 sensors detect vibration over the set value (logical AND) or where either one of sensors detects vibration over the set value (logical OR).

3.3.2 Visual Mudflow Measuring Equipment

The flowing condition of mudflow is taken by color TV camera and the pictures are monitored on a TV set in real time. The pictures are also recorded by VTR as required.

Starting/stopping of the TV camera and transmitter is controlled remotely from the Center.

When heavy rain is observed on the upstream by a small radar raingauge or the rainfall telemetering system or a detection signal is received from the mudflow sensing station, the operator at the Center manually starts the TV camera and transmitter by remote control and the field pictures are monitored on the TV set.

The necessary pictures are recorded by VTR and by repeated reproduction they can be used to study the conditions of the flow-down.

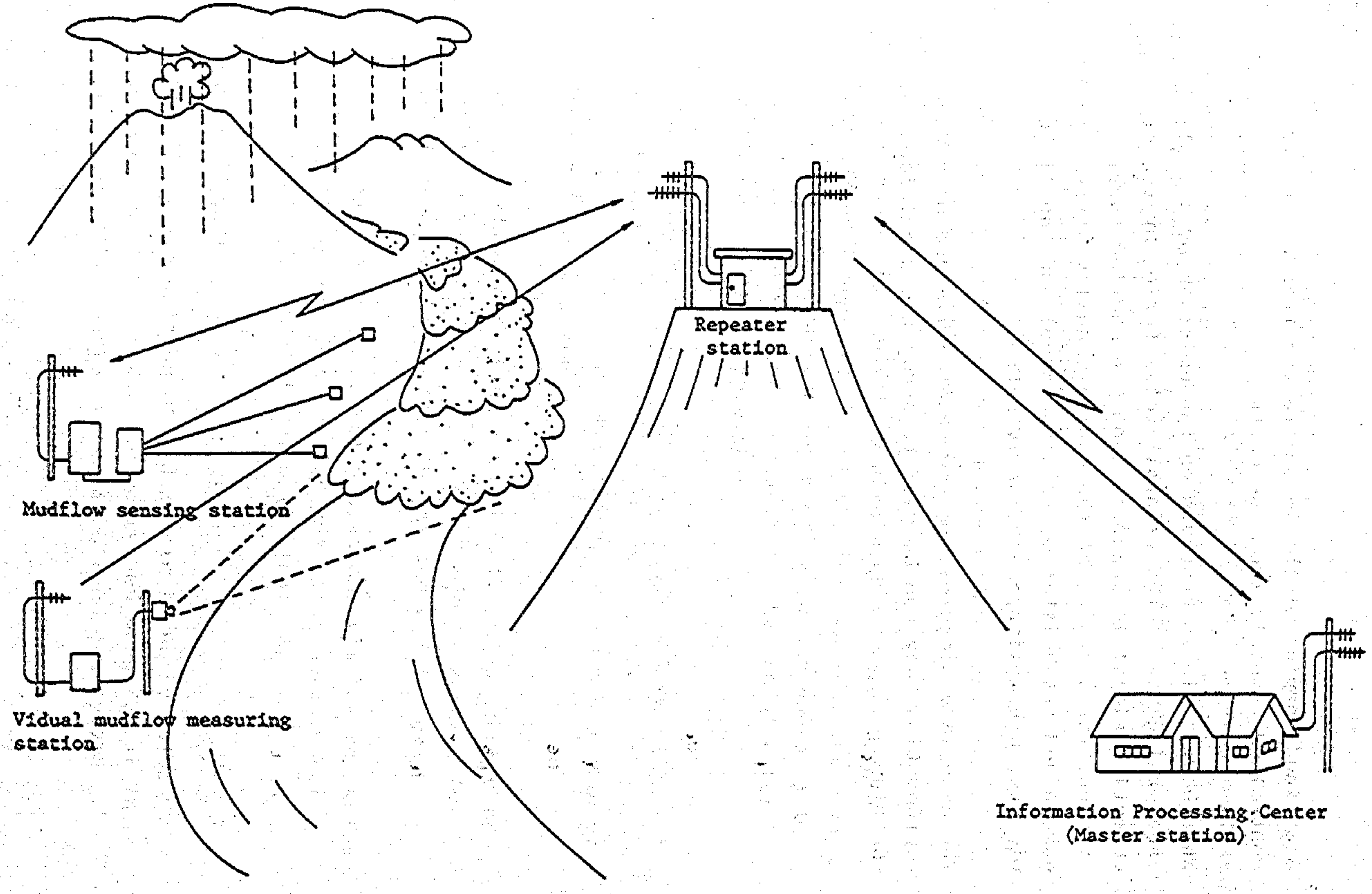


Fig-3.7 A Conceptual Sketch of Mudflow Observation System

4. PUBLIC INFORMATION SYSTEM

A speaker warning station is installed to inform the inhabitants of a mudflow danger zone immediately of an occurrence of mudflow.

Communication to ordinary areas is carried out by the existing ordinary communication system.

(1) Warning Equipment

The warning is broadcast to the inhabitants through speakers at each warning station controlled by the Center.

The warning stations are divided into 3 blocks by river basins and group control can be done for each block.

Broadcasting is carried out by radio with prerecorded tape or through microphone at the Center.

A warning tone through the speakers, can also be controled by the Center.

Further, the Center automatically checks the condition of the warning stations once a day and the results are recorded by typewriter.

(2) Items of Control

① Broadcasting of warning tone

② Starting broadcast
Broadcasting through microphone
Broadcasting by tape

③ **Stopping**

④ **Test**

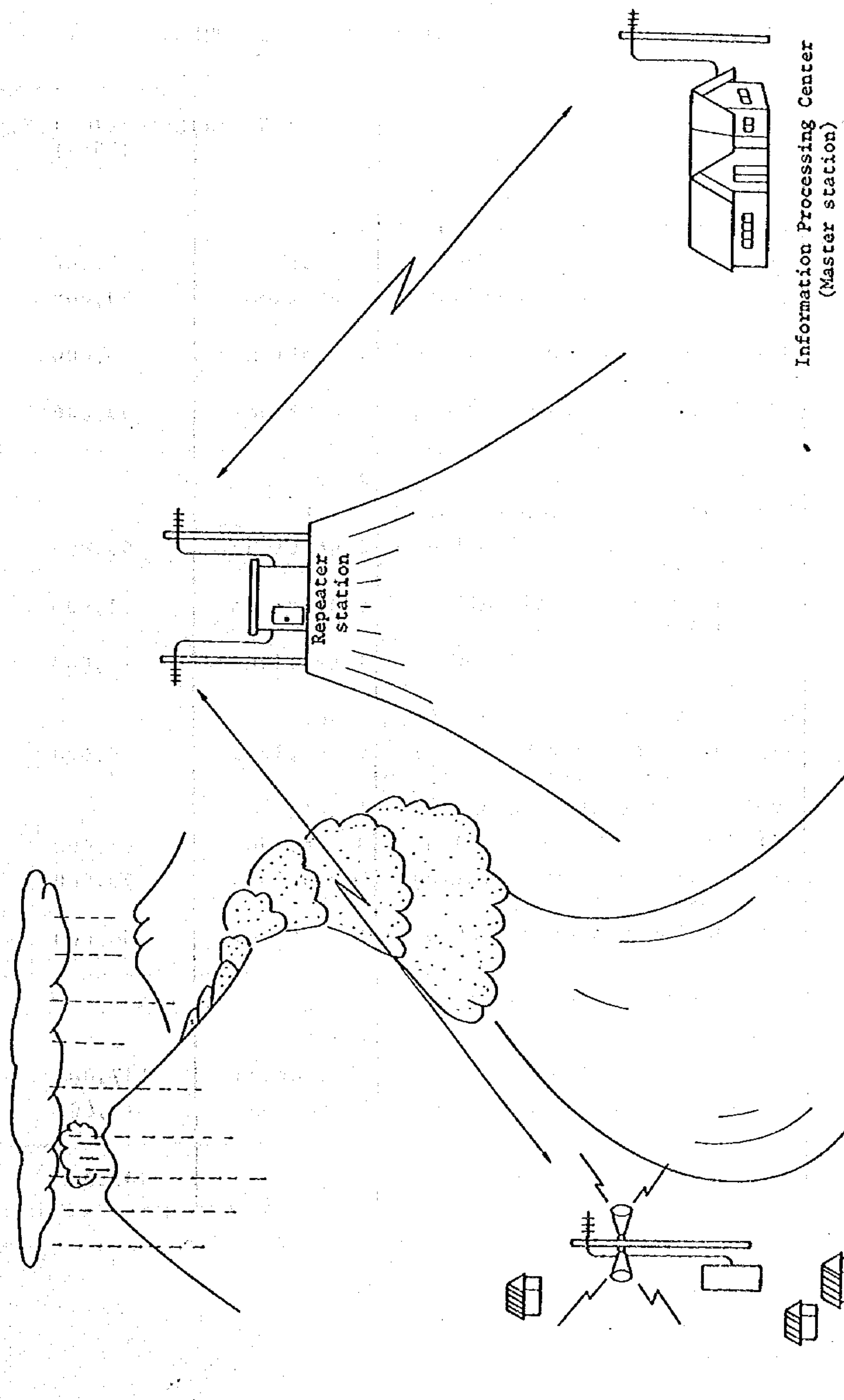


Fig-4.1 A Conceptual Sketch of Warning System

5. COST ESTIMATION OF MUDFLOW WARNING SYSTEM EQUIPMENT

Item No.	Description	No. of Units	Amount (C.I.F.) (10^3 ¥)
1.	Information processing system	1 set	
1.1	Information Processing center	1 set	
	(1) Small radar raingauge	1 station	143,000
	(2) Telemetering supervisory station	1 station	80,000
	(3) Visual mudflow receiving station	1 station	18,000
	(4) Warning control station	1 station	53,000
2.	Information system	1 set	
2.1	Rainfall observation system	1 set	
	(1) Telemetering monitoring station	2 stations	50,000
	(2) Telemetering rainfall gauging station	5 stations	61,000
	(3) Telemetering repeater station	1 station	19,000
2.2	Water-level observation system	1 set	
	(1) Telemetering water-level gauging station	6 stations	160,000
2.3	Mudflow observation system	1 set	
	(1) Mudflow sensing station	3 stations	67,000
	(2) Visual mudflow measuring station	2 stations	99,000
	(3) Mudflow repeater station	1 station	46,000
3.	Public information system	1 set	
3.1	Warning system	1 set	
	(1) Warning station	19 stations	147,000
	(2) Warning repeater station	1 station	19,000
	Total		962,000

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